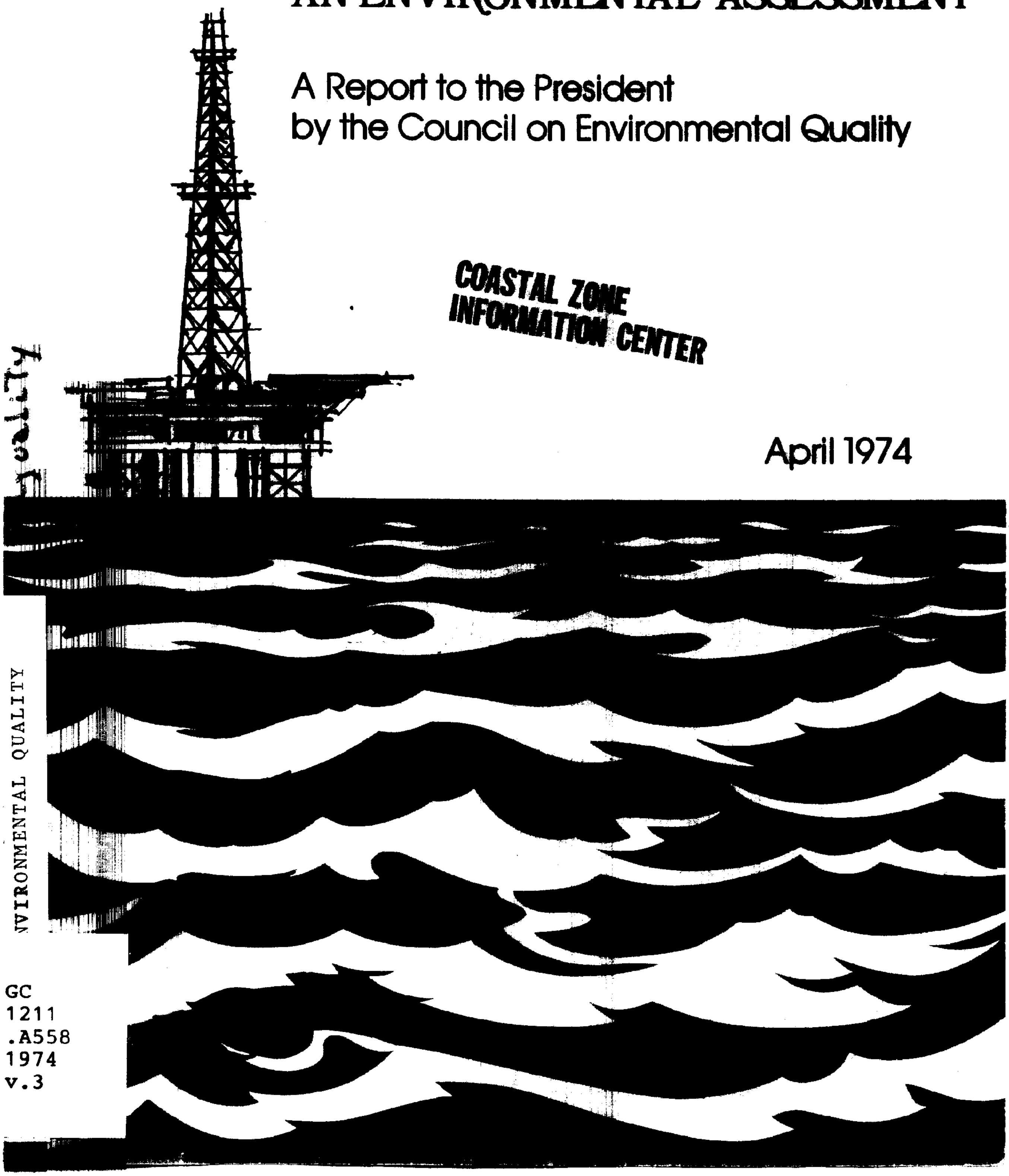
OCS OIL AND GAS — AN ENVIRONMENTAL ASSESSMENT

A Report to the President
by the Council on Environmental Quality

April 1974



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Volume 3

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The Effect of Natural Phenomena on OCS Gas and Oil Development

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1. INTRODUCTION

1.1 Background

Analysis of the geologic structures of the Atlantic Outer Continental Shelf and the Gulf of Alaska, has led geologists to conclude that large reserves of petroleum deposits may exist in each area. The development of these reserves could alleviate shortage of petroleum products in the United States over the next decade and lessen dependence on oil imports. While development of these resources is clearly in the interest of the United States, unrestrained development can lead to serious environmental stress that can result in permanent damage to the ecological systems existing in each area. For this reason, the President's Council on Environmental Quality has undertaken a study of the technical, environmental, and economic factors that would be affected by OCS development. A team of government, academic and industry experts has been assembled to investigate various facets of the proposed developments, predict the threats that will exist and propose safeguards that can be taken to minimize the environmental impact. Tetra Tech, Inc. was selected to investigate the effect of natural phenomena on offshore development. The specific tasks were to:

1. Provide descriptions of the physical systems associated with Outer Continental Shelf petroleum production and the natural forces to which they will be exposed.
2. Determine the individual and collective oil spill probabilities for the physical systems described above.
3. Define the potential volumes of oil that would be released as a result of the effects of natural phenomena.

A letter of intent was issued on 1 October 1973 and a contract was executed on 1 November 1973.

1.2 Scope and Depth of the Analysis

The physical systems associated with petroleum production have been grouped into four natural groupings: those used for exploration, for production, for storage, and for transportation. Descriptions of each are given in the Appendix.

The natural phenomena that were considered included severe storms, the tidal surge associated with severe storms, currents, ice, earthquakes and tsunamis. Recurrence values for each were determined using data from various sources. The National Oceanographic and Atmospheric Administration (NOAA) supplied wind and wave data, icing data and historical summaries of earthquake events. Representatives from the oil industry supplied additional climatic and oceanographic data. Data on tsunami occurrence and magnitude was derived from published accounts and summaries as well as in-house records of events. The recurrence relations for both earthquakes and tsunamis are considered "worst case" values. The actual occurrences will probably be less frequent.

Using the Tetra Tech tsunami propagation model, several calculations were made to determine the wave heights that would occur on the coastal perimeter of the Gulf of Alaska due to local earthquakes occurring at various locations in the Gulf. However the increase in wave heights due to local conditions such as harbor resonances, edgewave effects and so forth were not included. When specific harbor sites are considered or proposed, a detailed calculation should be made.

The scope of the study did not include calculating the natural phenomena forces that structures would have to withstand. Nor were any "typical" structure designs proposed that would withstand prescribed force levels. Instead it was assumed that owners/operators would require that elements of the oil production system be designed to meet certain criteria such as the forces associated with the 100 year event, and that the design would have a certain factor of safety before collapse. Industry practice is to specify factor of safety values ranging from 1.25 to 2.0 depending on various factors such as cost and expected life. Tankers were an exception since their design is a complex tradeoff between buoyancy, stability, cost and expected life without consideration of natural phenomena that may be characteristic of particular areas. Furthermore, while tanker structural failure occurs frequently enough to warrant serious concern, the causes, when known, are invariably traced to lack of proper hull inspections and failure to use prudent seamanship when transiting severe storms paths.

Earthquakes frequently trigger wide areal losses in soil stability. This in turn leads to failure of foundations of structures and pipeline supports. Examples of soil stability failure are settlement of cohesionless soils, liquefaction of the soil, flow slides and liquefaction of thin sand layers. Very little is known about the mechanics of soil structural failure and it is not possible to predict the scale of ground movement. Accordingly, this important effect is not included in the study except to note the need for a thorough test boring program at the selected sites and to carefully plan the pipeline runs to avoid areas of having soil of questionable properties Finally, the study did not include an analysis of oil industry concepts still in the design and development stage. When these designs reach the stage where they are proposed for operational use, a thorough analysis should be made to determine if the environmental standards will be improved or jeopardized.

1.3 Organization of the Report

The report is divided into six sections and an Appendix. Section 1 describes the scope of the report and the depth of the analysis Section 2 summarizes the conclusions. Descriptions of the various natural phenomena are contained in Sections 3, 4, and 5 and their effect on the system is discussed in Section 6. This section also includes an estimate of the volume of oil at risk for each element of the system and gives the individual and collective oil spill probabilities for the systems. The description of the physical systems associated with the Outer Continental Shelf is included as an Appendix.

1.4 Acknowledgments

A study of this scope could not have been completed within the short time available without the wholehearted enthusiasm and cooperation of a number of well-qualified individuals within the company. Mr. John Tsern provided descriptions of the oil development system. Mr. Maynard Brandsma carried out the calculations of tsunami wave heights and Mr. Albert Yuen carried out the probability of failure calculations. Each made major contributions to this report.

In addition, two other individuals contributed significantly to the study. Dr. F. Hebard of the National Oceanographic and Atmospheric Administration provided valuable climatic data and other information relating to the overall program. Mr. H. Meyers of the National Geophysical and Solar-Terrestrial Data Center at Boulder, Colorado provided extensive listings of earthquake events for both OCS areas as well as assessments of data validity. Their contributions are appreciated deeply.

2. SUMMARY OF RESULTS AND CONCLUSIONS

2.1 General

Oil field development has been broken down into four constituent parts; Exploration, Production, Storage and Transportation. Natural phenomena are divided into climatic and oceanographic phenomena, earthquake phenomena, and tsunami phenomena. Natural phenomena can be a cause of oil spills during each step of the oil field development.

2.2 Climatic and Oceanographic Conditions

Most climatic and oceanographic conditions on the OCS pose less of a threat than those already faced in other world areas where oil development is underway. These include surface and subsurface currents, ice, and storm surges.

In general, storms in the Gulf of Alaska are less severe than those found in the North Sea. The same is true for storms occurring in the southern regions of the proposed Atlantic sites. In the central and northern Atlantic sites the storms are more severe than those in the North Sea. If structures can be designed to withstand the 100 year storm and have a factor of safety of 2.0 and presuming that field development will require 30 years, there is then a 0.93 chance that they will survive without collapse. If designed to withstand the 200 year storm with a safety factor of 2.0, the probability increases to 0.97.

2.3 Earthquakes

The Atlantic OCS is an area of moderate seismic activity. Earthquakes comparable to about Richter 7 in magnitude have been reported over the last several centuries. Most reported earthquakes have been located in the northern sector of the proposed development. Only one (estimated 7.2 Richter) was reported in the southern sector.

The Gulf of Alaska is an area subjected to frequent and severe earthquakes. Within the last 60 years there have been 8 recorded instances of earthquakes occurring in the Gulf of Alaska having magnitudes greater than Richter 7. The 1964 Prince William Sound earthquake was estimated to be between 8.3 to 8.6 Richter.

Damage from earthquakes is usually due to either structural failure caused by dynamic shaking or foundation failure due to loss of soil stability or strength. Modern analytical techniques exist to calculate the dynamic forces structures must withstand to survive major earthquakes. Once the forces are calculated, careful attention will have to be paid to use of stronger materials and better construction techniques in order to develop structural strengths necessary to survive earthquake vibrations in active seismic areas such as the Gulf of Alaska and, to a lesser degree, on the Atlantic OCS. This is especially true for large, bulky, underwater structures such as storage tanks. If a structure is designed to withstand an earthquake of magnitude 7.2 Richter with a factor of safety of 1.5, there is a 0.86 probability that it will survive over a 30 year field life in the Atlantic OCS but most likely to fail over the same time span in the Gulf of Alaska. If the design criteria are raised to 8.6 Richter, the chances of survival in the Gulf of Alaska will increase to about 0.51.

Loss of soil stability will have a damaging effect on all fixed structures. The most serious oil spills will be due to pipeline failure and collapse of underwater storage tanks. Estimates of oil that would be spilled in the event of a pipeline failure are 10,000 bbls or more. The volume spilled as a result of a storage tank failure could be 1,000,000 bbls or more. Platform collapse can also produce oil spills. However, the probability of an oil spill resulting from platform failure is small because of the use of safety valves that automatically close-off the well at or below the ocean floor.

2.4 Tsunamis

Tsunamis are divided into two categories--those that are generated at a source remote from the area of interest and those that are generated locally. There are no recorded instances of remote tsunamis causing damage along either OCS coastline and no record of destructive local tsunamis occurring along the Atlantic coastline. (The tsunami damage caused by the 1929 Grand Banks seismic event was limited to areas close to the generation point.)

A tsunami wave height greater than 6 foot has a 20% chance of occurrence on the Atlantic OCS during a 30 year field life. For the Gulf of Alaska, it is predicted that such waves will occur 6 times over the life of the field. The only deep water structures that can be seriously affected by tsunamis are underwater storage tanks. The increase in mean water level and in water particle velocity at depth produced by the long period tsunami wave exerts forces on the structure which can be greater than the severe storm design loads of the walls and foundation of the storage tank.

Underwater storage tanks now being used in the Persian Gulf and the North Sea can hold 500,000 bbls and 1,000,000 bbls respectively. Larger volume tanks are being planned.

Tankers moored at fixed berths are seriously threatened by tsunamis. The forces exerted by the tsunami bore can cause the tanker to break its moor and ground on the nearby shoreline. Several instances of this type of accident occurred during the 1964 Prince William Sound earthquake and in previous tsunami events.

Tankers carry from 500,000 to 2,000,000 bbls of oil. This oil is distributed in a number of center line and wing tanks. Grounding will often result in one or more tanks splitting and releasing their oil to the environment.

2.5 Conclusion

An analysis has been made of the various combinations of storage and transportation elements that would constitute the least likelihood of producing a large oil spill. The conclusion reached is that for the Atlantic OCS the use of pipelines to transport oil to shore storage has the lowest risk of a major oil spill due to natural phenomena. If the depth of water, the quality of soil, or cost limits the use of pipelines, then floating storage and use of feeder tankers is an acceptable alternate.

For the Gulf of Alaska, use of pipeline, ashore storage and tanker loading at a mooring bouy is recommended. As was the case in the Atlantic, if use of a pipeline is not possible, then floating storage and a single point type of moor is an alternate choice. Having a tanker moor at a fixed berth in any of the ports surrounding the Gulf of Alaska will expose the tanker to the possibility of serious damage being caused by a locally generated tsunami.

Because of the threat posed by earthquakes and tsunamis, the use of underwater storage in either area should be carefully weighed.

3. CLIMATOLOGY AND OCEANOGRAPHY

3.1 Atlantic Offshore Coastal Shelf

The general surface wind pattern along the Atlantic Coast is controlled largely by the position and intensity of the Bermuda-Azores high-pressure system. The major low-pressure storm systems which develop sweep through the regions in a north to east-northeast direction. They can be intense and severe, and are accompanied by strong, gusty winds and heavy seas. These extra-tropical cyclonic conditions occur most often during the winter months when the Bermuda-Azores high is located far to the southeast. Tropical cyclones (or hurricanes) also occur frequently. Most occur from June through November. Less than 3% occur outside this period. The maximum winds that are found along the Atlantic Coast are associated with the passage of these cyclones or hurricanes.

Using techniques developed by Thom, NOAA has calculated the maximum sustained wind occurrence probabilities for each of the five areas located along the Atlantic Coast (Figure 1). These are given below.

TABLE 1. MAXIMUM SUSTAINED WIND* (in knots) FOR EACH ATLANTIC OCS AREA

	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
Area 1	69	76	85	92	101
Area 2	66	73	83	91	102
Area 3	66	72	83	92	103
Area 4	69	79	94	109	126
Area 5	63	73	88	102	118

*Maximum sustained wind is defined as the average over a one minute period of the maximum measured wind. Maximum gust velocity is usually about 1.4 times the maximum sustained wind.

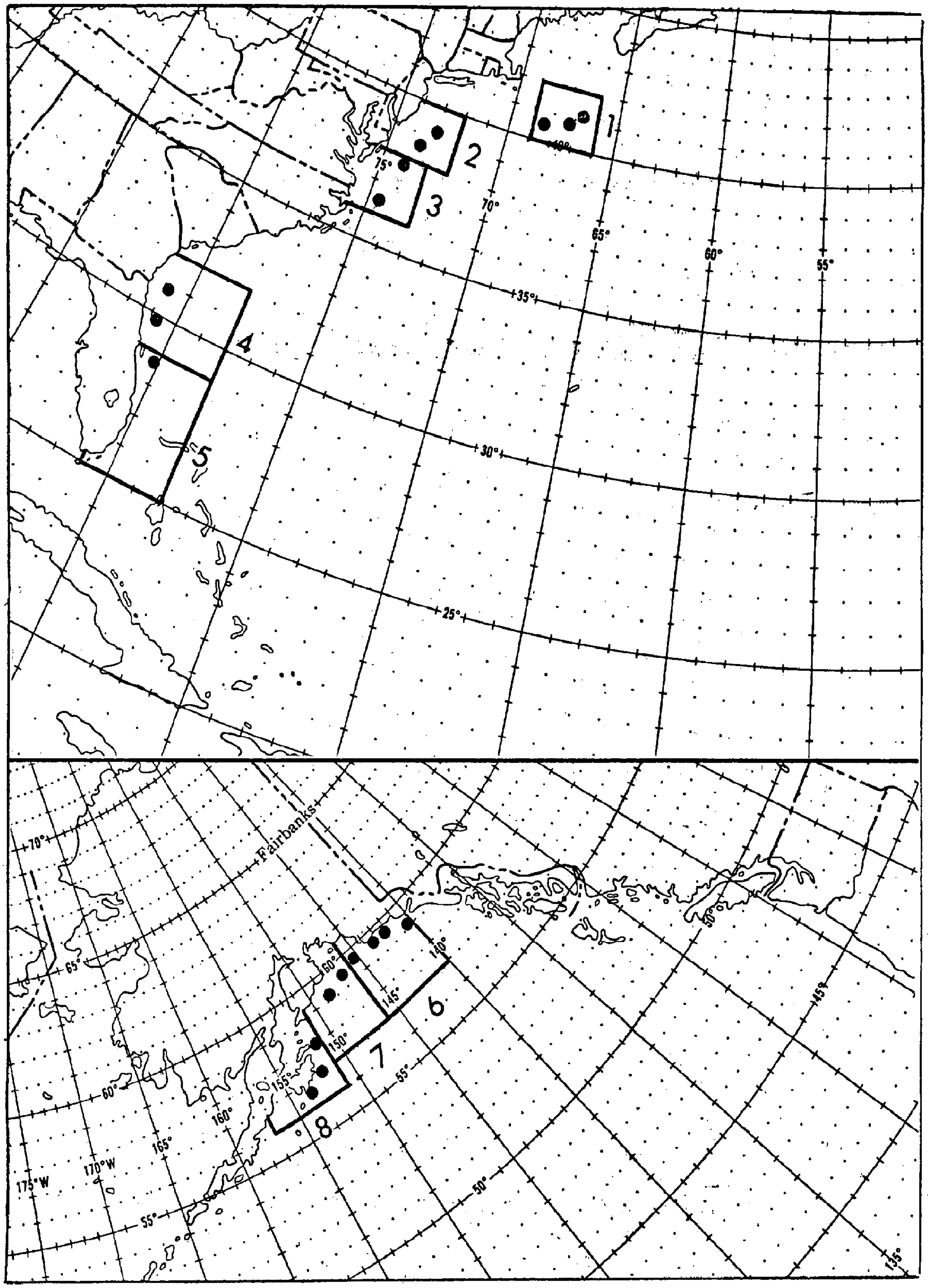

Figure 1. Location of Potential Oil Field sites and climatic zone boundaries designated by the National Oceanic and Atmospherics Administration

The maximum sustained winds are plotted in Figure 2 and compared with winds in the North Sea and the Gulf of Mexico. The less severe winds recur less frequently than those in the North Sea. On the other hand, the higher velocity winds occur more frequently on the Atlantic OCS. This will require that a greater design wind be used to achieve the same design objectives as those in use in the North Sea.

High waves along the Atlantic OCS can be generated by extratropical or tropical cyclones. Since extratropical are more frequent than tropical storms, the chance of high waves is greatest from about September through June. The highest waves recorded have occurred in the waters off Georgia, where they have reached 87 feet, and south of Cape Hatteras, where 60- to 70-foot waves have been reported.

Using the Thom recurrence values of wind and applying hind cast techniques, NOAA has calculated the maximum wave heights and significant wave heights for each of the occurrence intervals.

TABLE 2. MAXIMUM WAVE HEIGHT (in feet) FOR EACH ATLANTIC OCS AREA

	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
Area 1	79	86	95	103	112
Area 2	73	80	88	96	103
Area 3	82	89	99	107	116
Area 4	73	79	88	95	103
Area 5	61	66	73	79	86

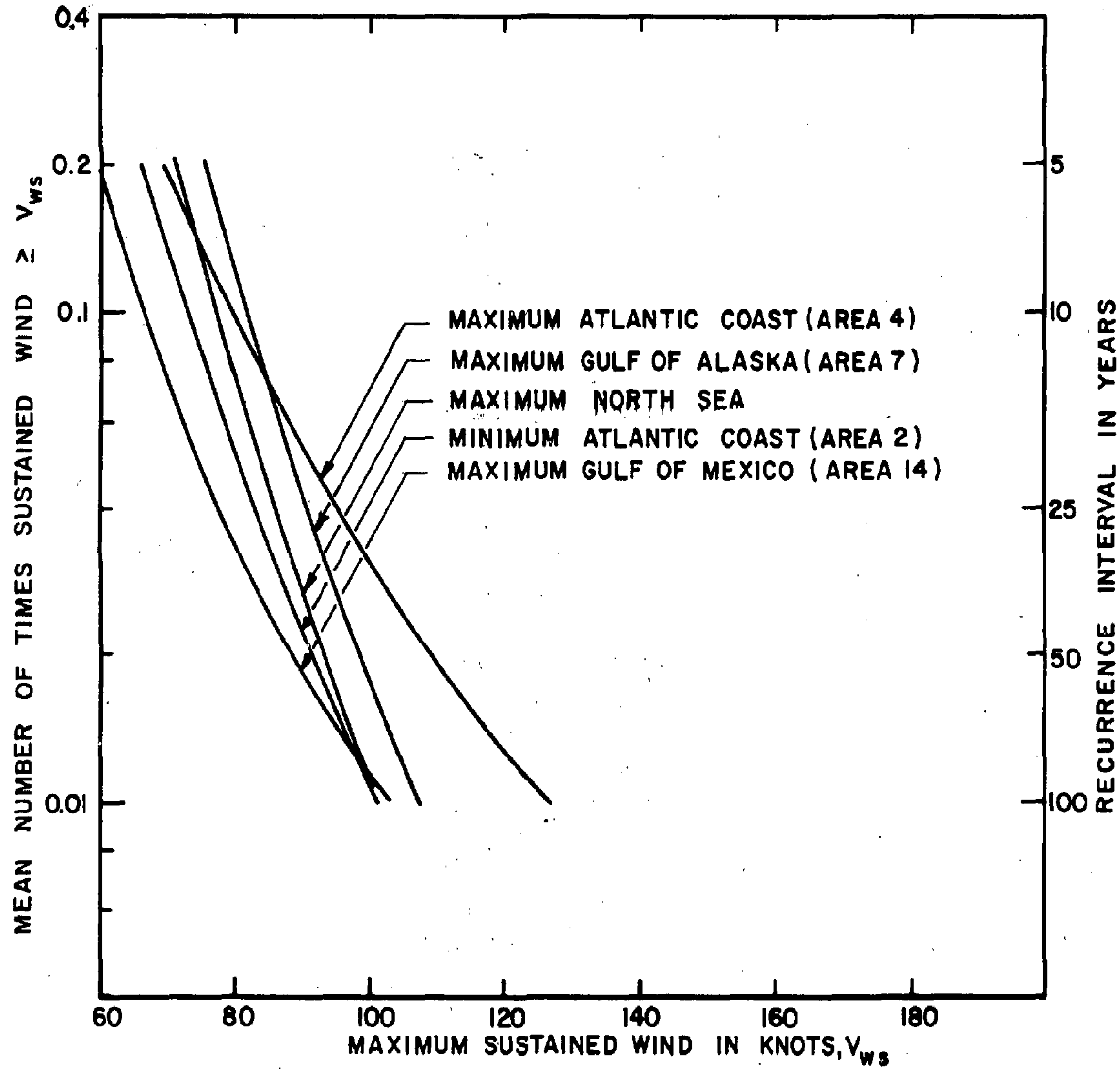

Figure 2. Comparison of Maximum Sustained Winds for the Atlantic Coast, Gulf of Alaska, Gulf of Mexico and the North Sea

TABLE 3. SIGNIFICANT WAVE HEIGHT* (in feet) FOR EACH ATLANTIC OCS AREA

	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
Area 1	44	48	53	57	63
Area 2	41	44	49	53	57
Area 3	46	49	55	59	64
Area 4	40	44	49	53	57
Area 5	34	37	41	44	48

Area 3 experiences more intense extratropical cyclones than Area 4. While the wind speeds in an extratropical cyclone are less than in a tropical cyclone, the persistence of the storm over days rather than hours results in generation of higher amplitude waves. For this reason the maximum and significant wave heights in Area 3 are greater than those in Area 4 although the maximum sustained winds are less.

The maximum and significant wave heights in Area 3 are compared with those in the North Sea and the Gulf of Mexico in Figures 3 and 4.

Currents are predominantly from north to south along the coast increasing in speed from about 0.5 knots at the north to 1.0 knots at the south. The Gulf Stream, with speed of 2.5 to 5.0 knots, parallels the southern Florida coast and approaches to within 5 miles of the shore. Tidal currents along the coast are generally less than 0.5 knots. Winds and storm surges may produce currents up to 3 knots. These currents will not be a critical factor in the design of offshore structures.

*Significant wave height is defined as the average of the largest third of all waves.

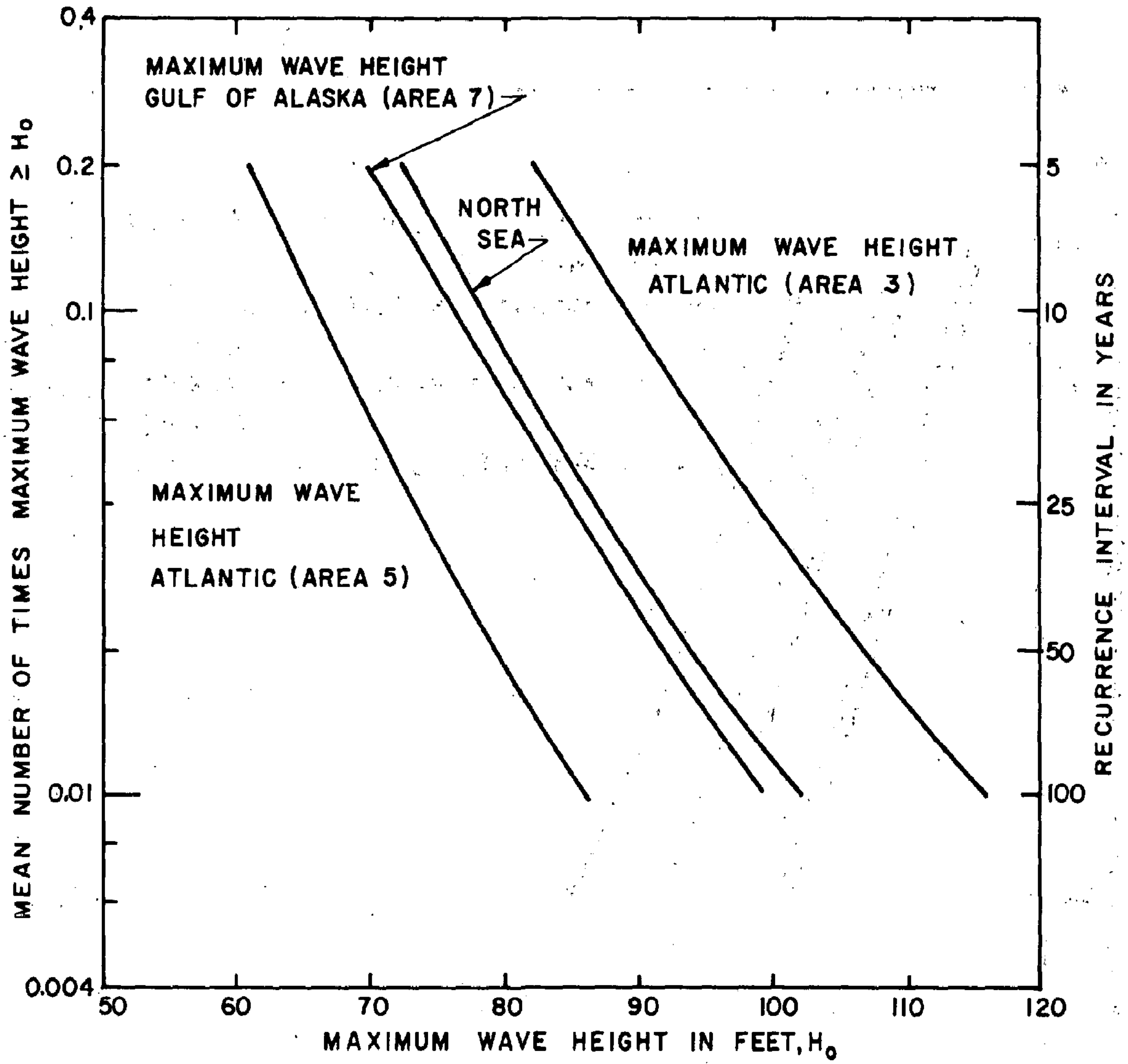

Figure 3. Comparison of Maximum Wave Heights for the Atlantic Coast, Gulf of Alaska and the North Sea

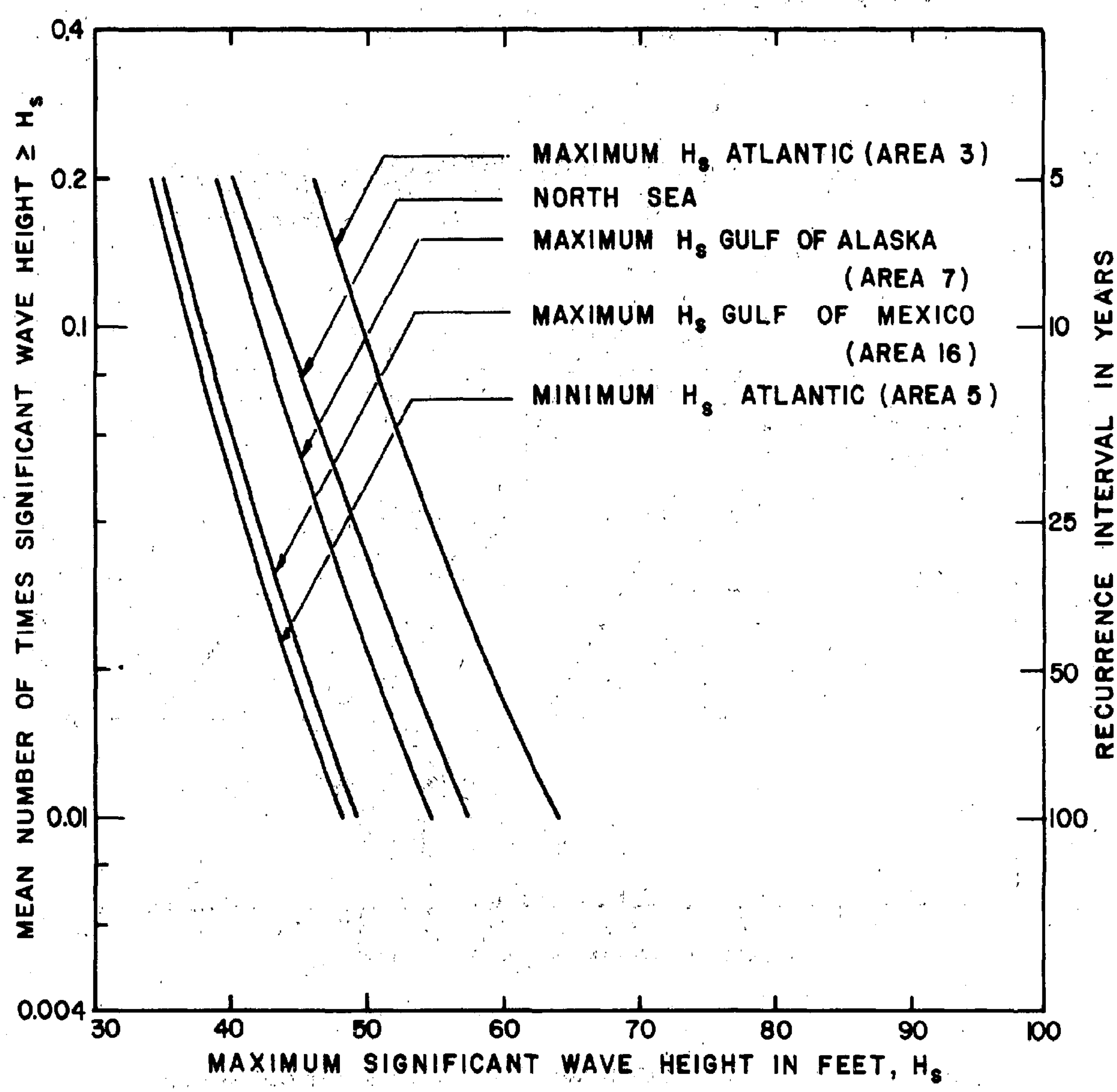

Figure 4. Comparison of Maximum Significant Wave Heights for the Atlantic Coast, Gulf of Alaska, Gulf of Mexico, and North Sea

Icebergs have been sighted off the Atlantic Coast but rarely as far south as the most northern development area. Those that have been sighted are small and should not threaten offshore structures.

Ice rafting, a common occurrence in northern coastal ports, and a serious design problem in areas having wide tidal swings such as found at Cook Inlet, is not a problem in the Atlantic coastal region where tides range from two feet in the south to about six feet in the northern areas.

Of more concern is the problem of ice accretion on ships and offshore structures. NOAA has estimated the likelihood of moderate icing* for the winter months as follows:

TABLE 4. MODERATE ICING PROBABILITY FOR ATLANTIC OCS AREAS (% frequency)

	Dec.	Jan.	Feb.	Mar.	Apr.
Area 1	1.8	5.6	8.3	2.2	.1
Area 2	2.0	5.8	7.1	.9	0

Severe ice accretion (build-up rate greater than $2\frac{1}{2}$"/day) is not likely to occur in the Atlantic regions being considered.

The hazard of ice accretion can be minimized or eliminated by providing heating coils, expandable boots, and, as a last resort, use of axes and chipping hammers.

* The Environmental Data Service National Climatic Center defines moderate ice accretion as having a build-up rate of $1\frac{1}{2}$ to $2\frac{1}{2}$ inches per day.

Storm surges often accompany the passage of tropical and extratropical cyclones. Maximum ambient water levels as high as 15 feet* above mean low water have been recorded and heights of 10 feet are common at many points along the shoreline during severe storms.

Storm surges are a shoreline phenomenon and as such do not hazard offshore structures. In the shoreline area they can damage and destroy facilities located on tideland sites. Storage tanks that have been improperly sited are the structures most frequently affected. Placement of structures on higher ground or installing adequate dikes eliminates the oil spill problems associated with storm surges.

3.2 Gulf of Alaska

The primary feature controlling the weather in the Gulf is the semi-permanent Aleutian Low. This cyclone usually appears in September moving gradually westward in winter and spring. Late fall and early winter are the seasons of strongest pressure gradients and, in general, the stormiest part of the year. The warm months bring the disintegration of the Aleutian Low, and the area falls under the influence of the North Pacific subtropical high.

During five of the six months from November through April more storms are found in the Gulf of Alaska than in any other part of the Northern Hemisphere. These storms move in from west and southwest and move out to the southeast. Formation and intensification of storms can take place in the Gulf in all seasons.

* Maximum of astronomical tide + storm surge + barometric occurring simultaneously.

The rim of high coastal mountains impede the frequent storms that move in from the southwest. In some cases these storms weaken and disappear but frequently they retain their intensity and stagnate in the Gulf for days.

The winds over the Gulf are generally southwesterly to westerly in the summer months and easterly the rest of the year. Average speeds are highest in late fall and early winter and are generally above 15 knots. Gale-force (≥ 34 kt) winds can occur year round although they are rare during the summer months. Gusts of 60 knots or greater occur almost monthly during the winter season.

Using statistical methods developed by Thom, the National Oceanographic and Atmospheric Administration has calculated recurrence values for maximum sustained winds for Areas 7, 8 and 9 (See Figure 1).

TABLE 5. MAXIMUM SUSTAINED WIND (kt) FOR EACH GULF OF ALASKA OCS AREA

	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
Area 6	71	77	86	93	101
Area 7	75	82	91	99	107
Area 8	69	75	84	91	98

These values are also plotted in Figure 2 and compared with similar wind calculations for the North Sea and the Gulf of Mexico. In general maximum winds in the Gulf of Alaska are 10% higher than those in the North Sea and about 30% higher than those that occur in the Gulf of Mexico for the same probability of occurrence.

The seasonal distribution of waves closely follows that of high winds. Waves ≥20 foot have been observed in the months from September through April and the significant wave heights are higher than those found in the North Sea and the Atlantic OCS areas (see Figure 5).

Using the Thom wind recurrence intervals and recognized hindcast techniques, NOAA has calculated the recurrence intervals for each area:

TABLE 6. MAXIMUM WAVE HEIGHT (ft) FOR EACH GULF OF ALASKA OCS AREA

	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
Area 6	62	68	75	81	88
Area 7	70	76	85	92	99
Area 8	59	64	71	77	83

TABLE 7. MAXIMUM SIGNIFICANT WAVE HEIGHT (ft) FOR EACH GULF OF ALASKA OCS AREA

	5 yr.	10 yr.	25 yr.	50 yr.	100 yr.
Area 6	34	38	42	45	49
Area 7	39	42	47	51	55
Area 8	33	35	39	43	46

As would be expected, the maximum wave heights occur in the central region (Area 7), the region where the storms tend to stagnate and intensify. It is also important to note that the wave heights in all three areas are less than those found in four of the five areas of the Atlantic OCS.

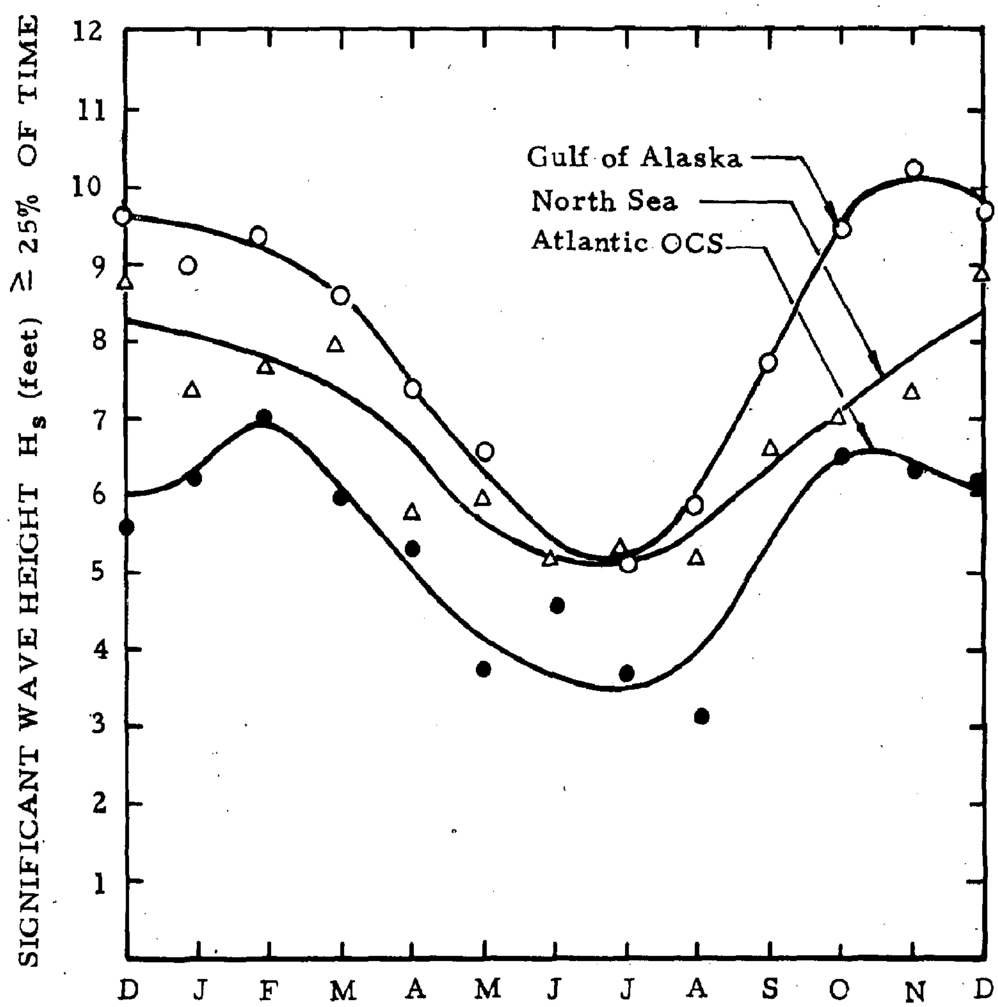

Figure 5. Monthly Variation in Significant Wave Height for Atlantic OCS, Gulf of Alaska and North Sea

The recurrence intervals have been plotted in Figures 3 and 4 and compared with those in the North Sea and the Gulf of Mexico. Although greater than those found in the Gulf of Mexico, they are less than those occurring in the North Sea.

Very little data is available on measured currents in the Gulf of Alaska. Usual practice has been to calculate values of current as the sum of tidal current, drift currents, and currents associated with the general circulation pattern in the area. These calculations indicate a maximum surface current varying from 3 to 4 knots can be expected, decreasing to a knot at depths of 1000 feet.

Many glaciers are found on the perimeter of the Gulf of Alaska. The glacier faces are fronted by small inlets created by the advance of the glacier which occurred centuries before during colder eras. The inlets are bounded by a moraine bar which marks the line of furthest advance. Icebergs are frequently found in the glacial inlets. They are produced by calving at the glacier face. However, the bar at the mouth of the inlet prevents all but the smallest bits from entering the open water. For this reason icebergs are not a hazard to Gulf of Alaska operations.

Ice accretion is a more serious problem in the Gulf of Alaska than was the case in the North Atlantic. NOAA has predicted the following frequencies for moderate and severe ice accretion.

TABLE 8. ICING PROBABILITY FOR GULF OF ALASKA AREAS (% frequency)

		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Area 6	Mod.	.3	1.0	3.6	8.3	2.2	2.8	.1	---
	Sev.				None				
Area 7	Mod.	.1	1.2	8.9	7.5	6.4	9.1	.9	.2
	Sev.	---	---	---	---	.6	---	---	---
Area 8	Mod.	.6	4.3	22.0	11.0	20.0	9.5	3.2	.2
	Sev.	---	---	---	.2	.7	.5	---	---

Comparing the data in Table 8 with that in Table 4 it is clear that conditions for icing occur much more frequently in the Gulf and extend over a much larger period of time. Provision for ice removal will be even more important than it was for the Atlantic regions.

There is no storm surge data available for the Gulf of Alaska regions. Calculations of increases in elevation due to astronomical tides, wind-driven surge, and response to barometric variations show that the total rise should be less than 20 feet. As was the case in the Atlantic this should pose no problem provided onshore structures are properly sited.

4. EARTHQUAKES

4.1 General

The theory of plate tectonics has been generally accepted to explain the occurrence of most earthquakes. This theory postulates the concept that the earth is slightly plastic. This plasticity allows the continental and oceanic plates to drift slowly over its surface, fracturing, reuniting, and possibly growing in the process. In areas where plates are separating there is a build-up of tensile stress which is relieved from time to time by fracturing. The fracture zone is marked by the occurrence of moderately severe earthquakes. In regions where plates are joining, compressive stresses develop. These stresses are relieved by fracturing along the fault. The areas of stress build-up are marked by dip strike and slip strike faults and the occurrence of severe shallow and deep focus earthquakes.

The theory postulates that the North Atlantic plate is slowly moving away from the African plate and colliding with the Pacific Ocean Basin plate. The rift zone is marked by the Mid-Atlantic Ridge. The strike zones in the Alaskan region are marked by faults and trenches such as the Alaskan-Lake Clark fault and Aleutian trench. One therefore expects moderately severe earthquakes in the Atlantic and severe earthquakes on the Alaskan perimeter and such is the case.

Earthquakes are also observed in areas which are distant from rift and strike zones. These earthquakes are generally due to subsurface consolidation of large soil volumes. They are much less frequent, less severe and generally deeply focused. They rarely cause structural damage to structures and facilities. Most earthquakes in the Atlantic coastal areas are attributed to this cause.

4.2 Atlantic Offshore Continental Shelf

Tectonic activity along the North Atlantic rift, the St. Lawrence Valley, the Laurentian Trough and the Cabot fault can produce moderately high seismic activity. In addition, settling of the coastal plain sediments east and south of the Appalachian range can produce occasional strong shocks.

Historical records of earthquakes for the past 300 years have been reviewed. The significant ones (Mercalli intensities greater than IV) are listed in Table 9. While seismic activity is considerably less than in other seismically active areas, the intensity can be almost as severe.

The location of each of these earthquakes has been plotted in Figure 6. The Richter magnitudes, which can be roughly correlated with the observed Mercalli Intensity*, are shown in parenthesis at the location of each event. One notes that the predominant number of earthquakes occurred in the northeastern section of the Atlantic Coast in the vicinity of the first four proposed sites. Only one earthquake (albeit one of the most severe) has been recorded in the southern portion of the shelf.

*While Mercalli intensities are not directly correlatible with Richter magnitude, the effects can be roughly correlated. If this is done, an intensity of X would correspond to a Richter 7.2 and an intensity of XII would correspond to a magnitude of 8.4 or about the magnitude of the Alaskan Earthquake of 1964.

TABLE 9. MODERATE TO SEVERE ATLANTIC COAST EARTHQUAKES RECORDED SINCE 1727.

Date	Lat. N	Long. W	Estimated Modified Mercalli Intensity	Correlated Richter Scale Magnitude	Felt Area Sq. Miles
1727 NOV. 9	42.8°	70.8° (Mass.)	VIII	6	75,000
1737 DEC. 18	40.8	74.0 (N.J.)	VII	5-6	
1755 NOV. 18	42.5	70.0 (Mass.)	VII	5-6	300,000
1817 OCT. 5	42.5	71.2 (Mass.)	VII-VIII	6	
1880 JAN. 2	22.8	80.8 (Cuba)	VIII	6	65,000 (U.S.)
1884 AUG. 10	40.6	74.0 (N.J.)	VII	5-6	70,000
1886 AUG. 31	32.9	80.0 (Charleston, S.C.)	IX-X	7	2,000,000
1897 MAY 31	37.3	80.7 (W. Va.)	VII	5-6	280,000
1904 MAR. 21	45.0	67.2 (Maine)	VII	5-6	150,000
1927 JUN. 1	40.3	74.0 (N.J.)	VII	5-6	3,000
1929 NOV. 18	44.0	56.0 (Grand Banks)	X	7	80,000 (U.S.)
1940 DEC. 20	43.8	71.3 (Maine)	VII	5-6	150,000
1944 SEP. 4	45.0	74.8 (St. Lawrence Valley)	VIII	6	175,000
1957 APR. 26	43.6	69.8 (Maine)	VI	5	31,500

MODIFIED MERCALLI INTENSITY SCALE OF 1931 (ABRIDGED)

VI Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale.)

VII Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale.)

VIII Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse: great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, momuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX Rossi-Forel Scale.)

IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel Scale.)

X Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel Scale.)

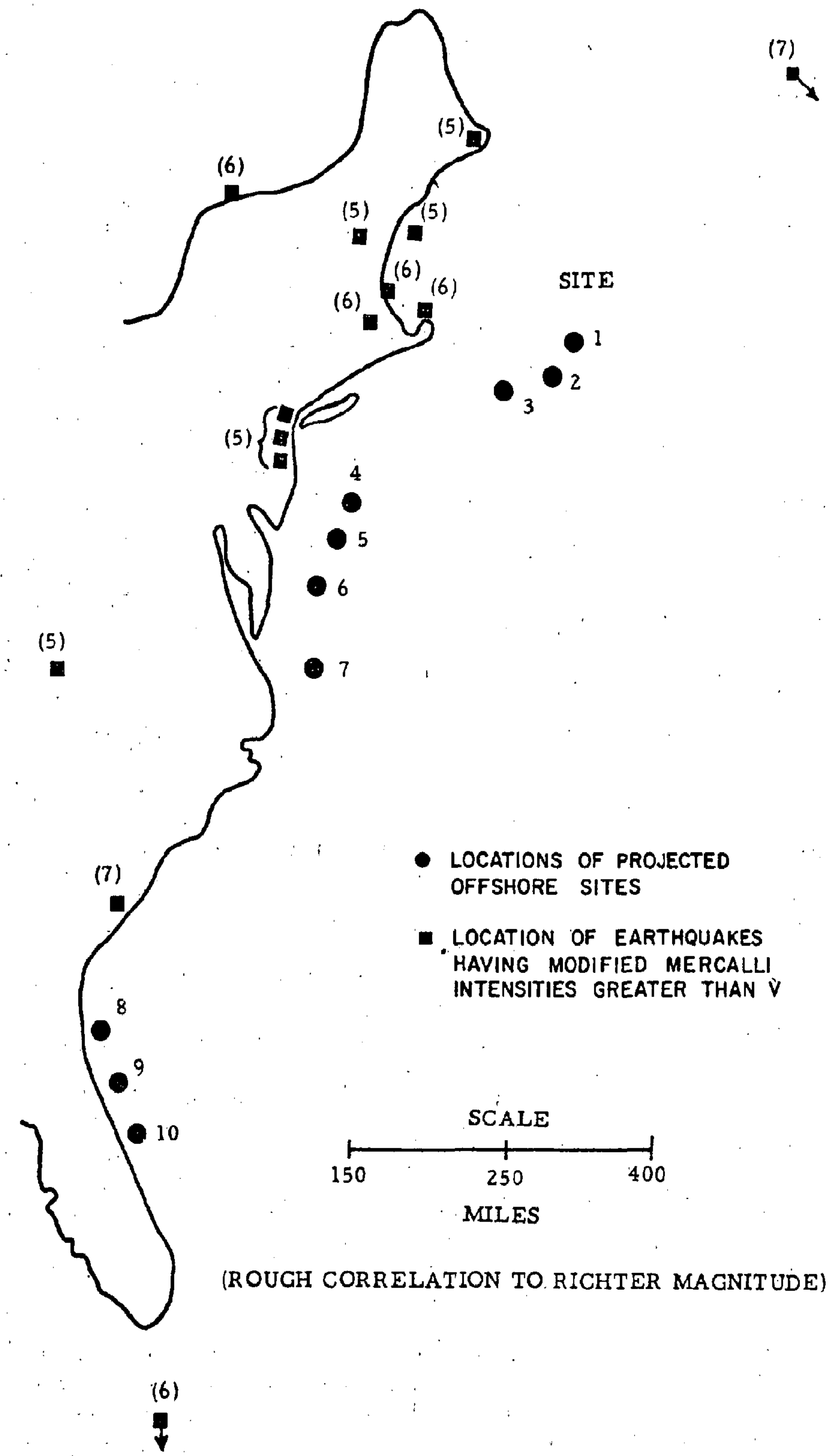

Figure 6. Locations of moderate to severe Atlantic Coast earthquakes since 1727 (Based on historical data supplied by NOAA)

Two earthquakes have occurred that have been classified X on the modified Mercalli scale. Earthquakes of this intensity will cause considerable damage even to well designed structures, and produce foundation damage with the possibility of collapse. Ground cracking will be noticed and landslides can be expected. One of these, the 1929 Grand Banks earthquake, caused a turbidity current* which destroyed communication cables over a wide area.

4.3 Gulf of Alaska

Alaska and the Aleutian Islands are part of the great seismic belt that circumscribes the Pacific Ocean Plate. Earthquake activity here is more frequent and more intense than in any of the areas on the Atlantic offshore shelf. In the interval between 1899 and 1917 there were four earthquakes in the vicinity of the proposed sites that had magnitudes greater than 7.8. Since then there have been eight earthquakes having magnitudes greater than 7.0. The dates and magnitudes are given in Table 10 and the locations are shown on Figure 7.

The seismic activity in the Alaska area is separated into two zones. One zone, approximately 200 miles wide, extends to the left of Longitude 146° from Fairbanks through the Kenai Peninsula to the near Islands. The second zone east of longitude 144° begins north of Yakutat Bay and extends southeastward to the west coast of Vancouver Island. Opinion is divided as to whether the area between the two zones is a region of unrelieved strain having a high

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* The ground motion can force a portion of the bottom sediment into suspension in the overlying water. If enough sediment can be stirred into suspension the resulting dilute mud may become sufficiently dense to flow down a slope under the force of gravity. This flow is termed a turbidity current on suspension flow.

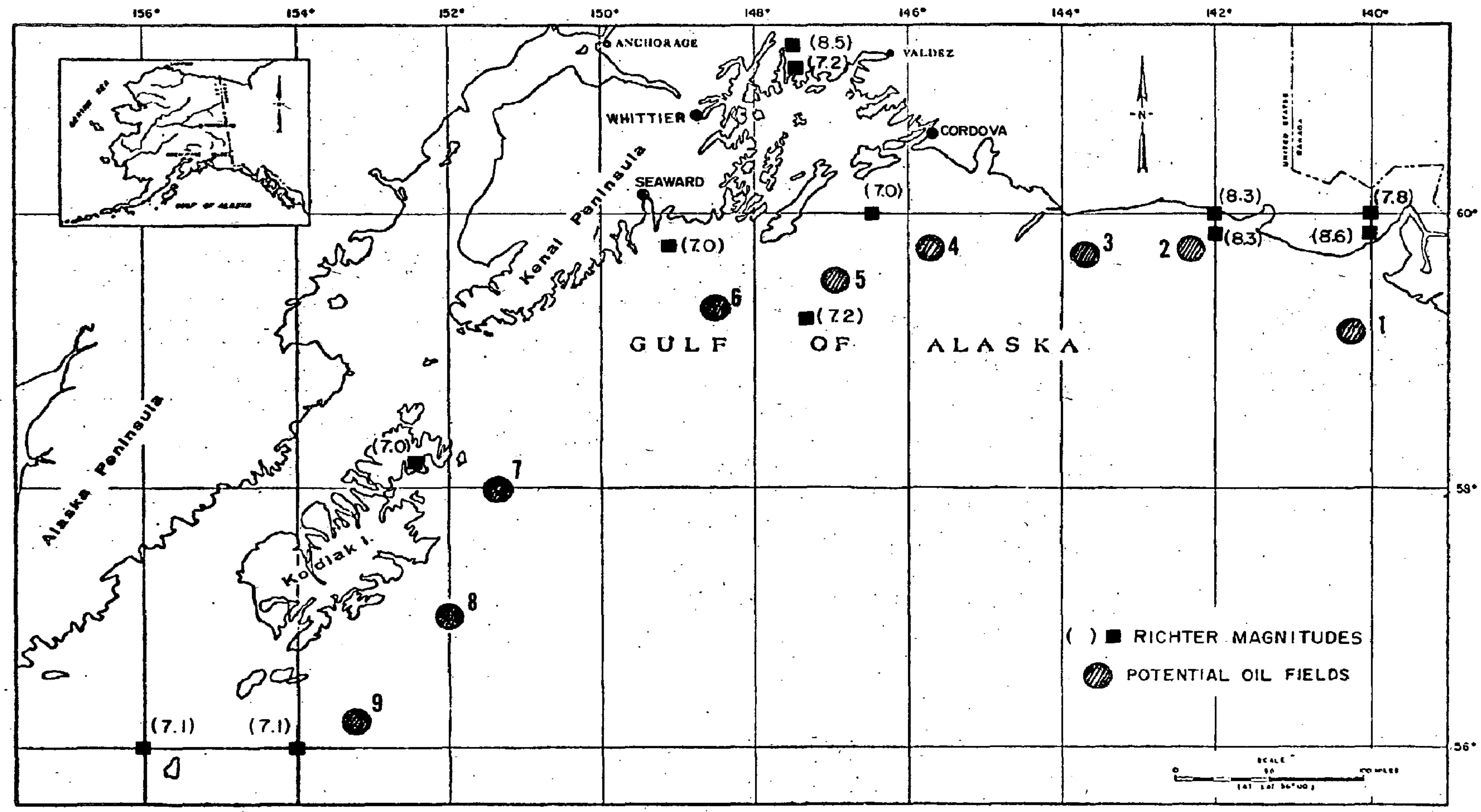

Figure 7. Locations of severe Gulf of Alaska area earthquakes since 1899. (Based on historical data supplied by NOAA)

TABLE 10. PROMINENT GULF OF ALASKA EARTHQUAKES

Great Earthquakes (M > 7.7), 1899-1917

Greenwich Date	Epicenter Location		Focal Depth (km)	Richter Magnitude M
9/4/1899	60N	142W	--	8.3
9/10/1899	60N	140W	--	7.8
9/10/1899	60N	140W	--	8.6
10/9/1900	60N	142W	--	8.3

Major Earthquakes (M ≥ 7.0), 1918-1973

Date	Location		Depth (km)	M
6/21/1928	60N	$146\frac{1}{2}$W	--	7.0
5/4/1934	$61\frac{1}{4}$N	$147\frac{1}{2}$W	80	7.2
1/12/1946	$59\frac{1}{4}$N	$147\frac{1}{4}$W	50	7.2
9/27/1949	$59\frac{3}{4}$N	149W	50	7.0
4/10/1957	56N	154W	--	7.1
2/6/1964	59N	156W	--	7.1
3/28/1964	61.1N	147.6W	20	8.3/8.6
9/4/1965	58N	$152\frac{1}{2}$W	19	7.0

probability of producing the next severe earthquake or whether the region is an area of naturally infrequent earthquakes.

The intensity and magnitude of earthquakes in the Alaskan region are as severe as any that occur throughout the world. In the 1964 Alaska earthquake (Richter 8.3 to 8.6), significant damage extended at least 90 miles from the epicenter. Permanent ground deformations occurred over 100,000 square miles. In the vicinity of Montague Island, vertical deformations of about 30 feet and horizontal deformations of about 80 feet were recorded. In addition, wide scale land slumping and slides were recorded throughout the central Alaskan coastal area.

4.4. Earthquake Recurrence Relations

While the plate tectonic theory provides a plausible explanation for zones of earthquake activity, it is not sufficiently developed to predict the frequency or intensity of earthquakes along rift or fault lines. For this it is necessary to rely on historical data. This was done for the study. Using data provided by NOAA, recurrence relations were constructed for the Gulf of Alaska and the Atlantic coastal area. These are shown in Figure 8 and illustrate the markedly less frequent occurrence of seismic activity on the Atlantic coast. It is also to be noted that the maximum reported earthquake correlated to 7.2 Richter while in the Alaskan region of interest there have been eight earthquakes within the past 55 years having magnitudes greater than 7.0 Richter.

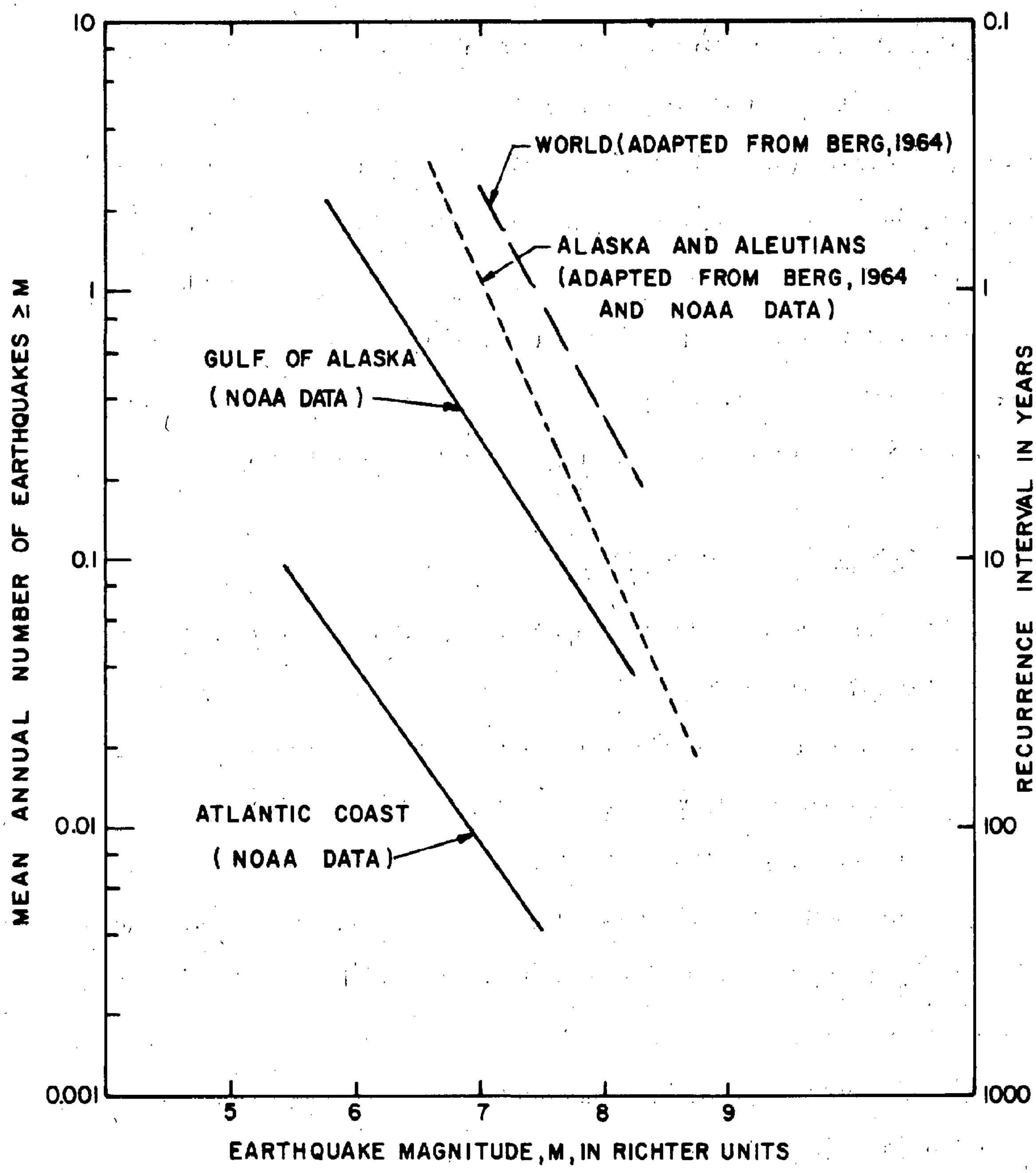

Figure 8. Comparison of frequency and magnitude of earthquakes in the Atlantic Coast, Gulf of Alaska, Alaska and World Regions

5. TSUNAMIS

5.1 General

Nearly all naturally occurring tsunamis are closely associated with large submarine earthquakes of Richter magnitude greater than about 6.5 and focal depths less than 50 kilometers. The mechanism of generation is generally due to vertical dislocations of the sea floor. Landslides, volcanic explosions and other phenomena associated with large ground motion can also produce damaging waves. However, the damage caused by these waves is limited to the vicinity of the source.

Tsunamis are divided into two categories: those that are generated at a source remote from the area of interest and those that are generated locally. A review of the historical records of tsunamis indicates that no remote tsunamis have caused damage in either the Atlantic Coastal area or on the perimeter of the Gulf of Alaska. This is not surprising since an analysis of the tsunamogenic regions in the Atlantic and Pacific basins confirm that the orientation of faults is such as to focus the wave in a direction different from that pointing to the areas of interest.

The historical records also show that there have been no locally generated tsunamis that have resulted in damage to the Atlantic Coast.* A plausible rationale can be proposed for this by considering Figure 9 which illustrates the relationship between the magnitude of a seismic event and the height of the wave near the generating source. As was noted earlier, the maximum magnitude earthquake that was believed

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*A number of locally generated tsunamis have occurred in the Caribbean chain of islands: Haiti (1775), Virgin Islands (1867; 20 feet), Puerto Rico (1918; 15-18 feet).

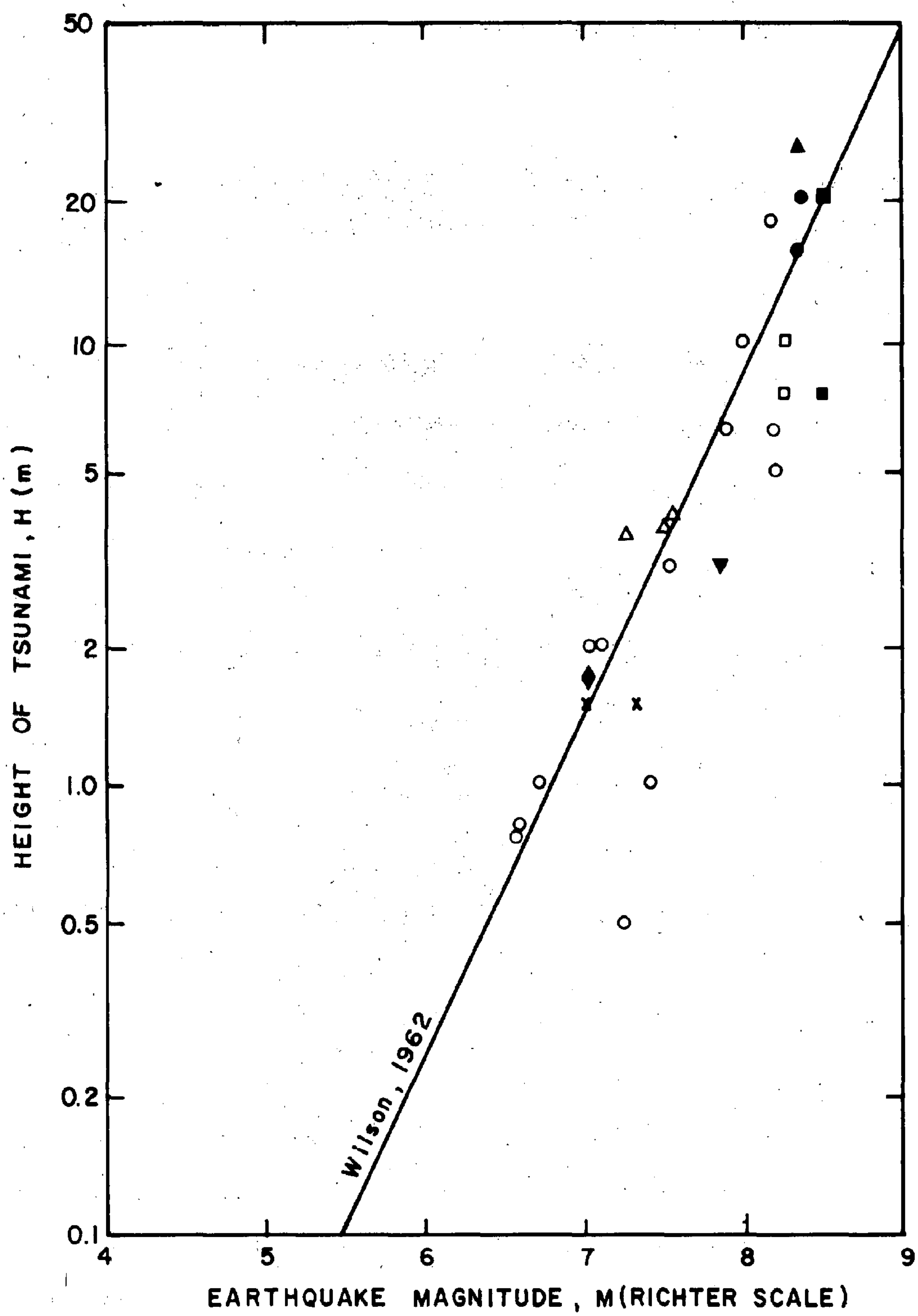

Figure 9. Correlation of Near Source Tsunami Height with Earthquake Magnitude (adapted from Wilson)

to have occurred in the Atlantic Coastal region was estimated to be about 7 Richter. The tsunami generated by this seismic event would not likely be greater than 6 feet and would not cause damage except if affected by unusual harbor and bay effects. The limitations of this rationale are obvious but it does support the contention that tsunamis do not pose a threat to Atlantic OCS development.

5.2 Gulf of Alaska

Historical records show that a number of destructive tsunamis have occurred in ports on the perimeter of the Gulf of Alaska. Two have been recorded in Valdez Bay within the last 70 years. Other ports that have experienced damaging tsunamis include Cordova, Whittier, Seward, Kodiak and Yakutat. All of these tsunamis were generated by sources close to the affected ports.

In the section on earthquakes it was pointed out that severe earthquakes occur frequently in the Gulf of Alaska. Applying again the rationale that the maximum tsunami wave height near the source is related to the magnitude of the seismic event, it can be seen that wave heights greater than 30 feet can be expected to be generated in this area. This is borne out by analysis of the waves generated in the 1964 Prince William Sound earthquake in which it was estimated that the maximum wave height exceeded 30 feet.

To determine the tsunami wave heights that could occur at points throughout the Gulf of Alaska a series of calculations were made in which a vertical uplift up 30 feet was assumed to have occurred at various points within the Gulf. The resulting tsunami wave was then allowed to propagate throughout the Gulf. Fig. 10 illustrates a typical case 30 seconds after the initial uplift. As can be seen, wave heights of 25 feet encircle the fault line and wave heights as much as 10 feet extend into Prince William Sound.

From these calculations a contour map of potential tsunami wave heights throughout the Gulf was developed. This is illustrated in Figure 11. One can see that the wave heights as high as 35 feet can occur in the vicinity of the platforms and can increase in height as the shoreline is approached.

Calculations were also made for various harbors surrounding on the Gulf of Alaska. One example is shown in Figure 12. The port of interest was Seward and the calculations are shown for seismic events located in a western Gulf location, central Gulf location and an eastern Gulf location. As expected the waves from the nearest seismic event produced the largest wave (Case 1) (26 foot above the previous still water level). However, the eastern seismic event, (Case 2), although located about 150 miles away produced a 10 foot wave. The western seismic (Case 3) event, which was oriented along the Northeast - Southwest fault propagated its waves in south easterly direction and did not produce a very high wave.

These calculations ignore the response of harbors to specific characteristics of the incoming tsunami wave such as direction of approach,

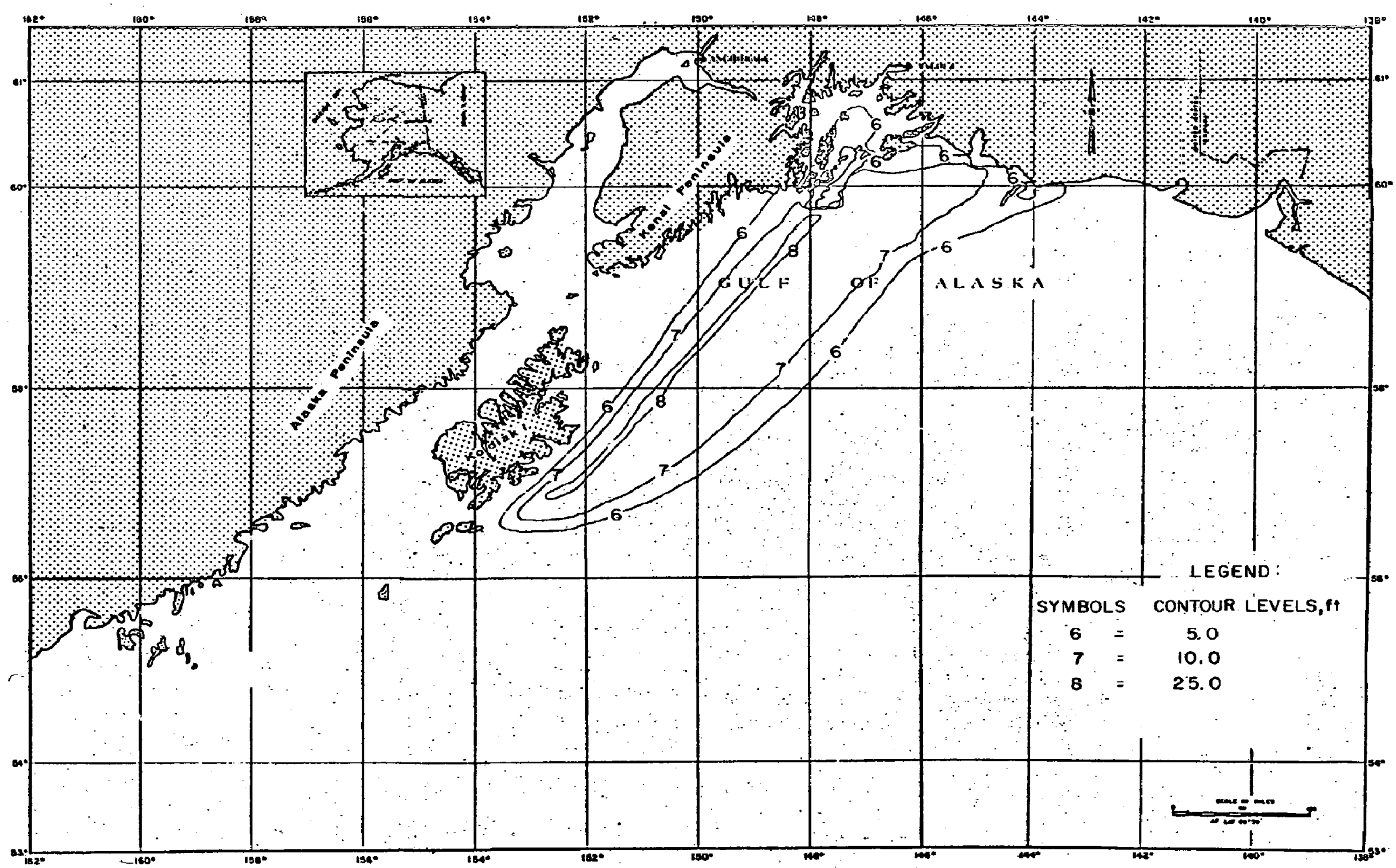

Figure 10. Calculated Tsunami Wave Height Contours for vertical uplift of 30 feet centered on the 1964 Prince William Sound earthquake fault. (t = 30 seconds after uplift.)

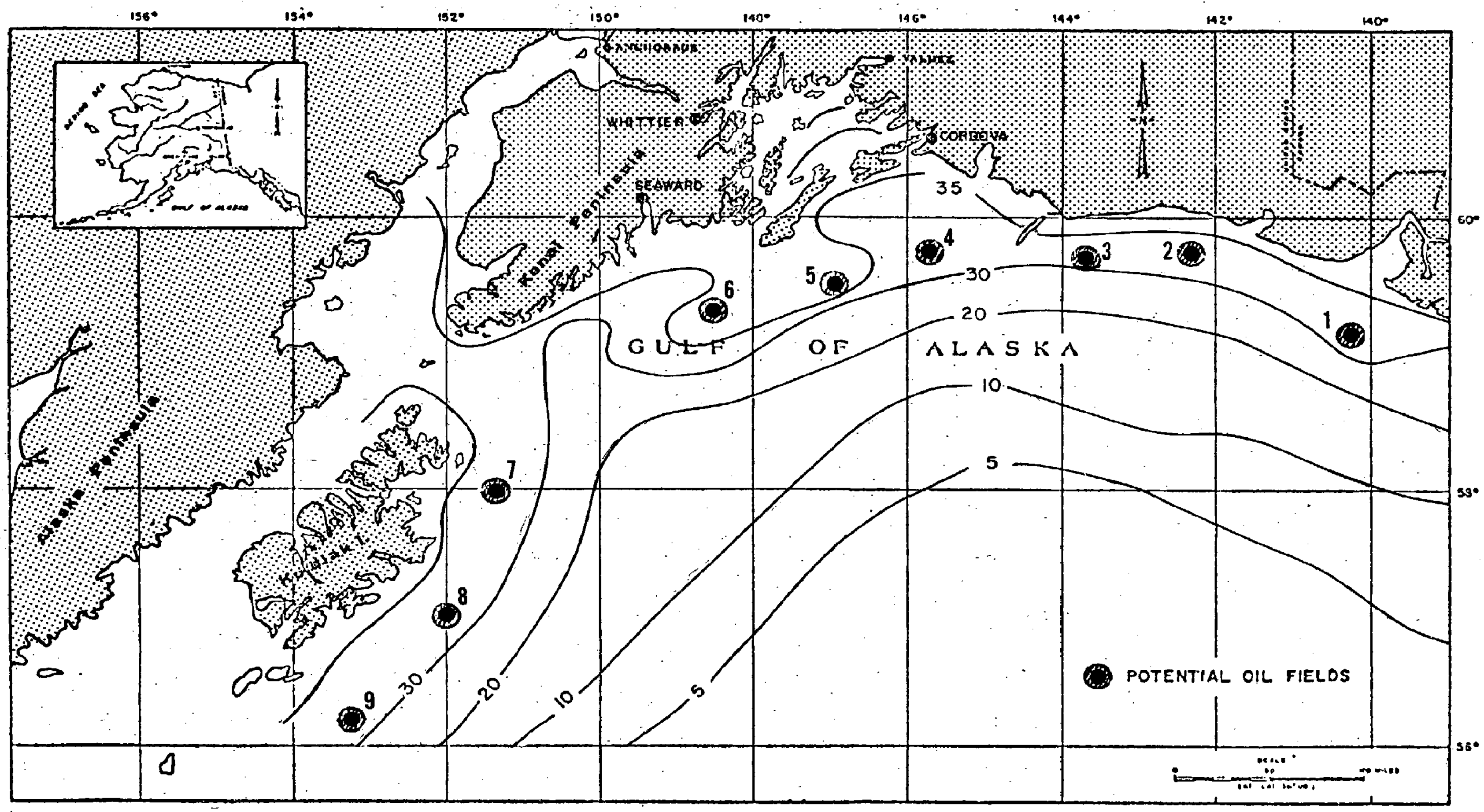

Figure 11. Tsunami Height Distribution in Gulf of Alaska

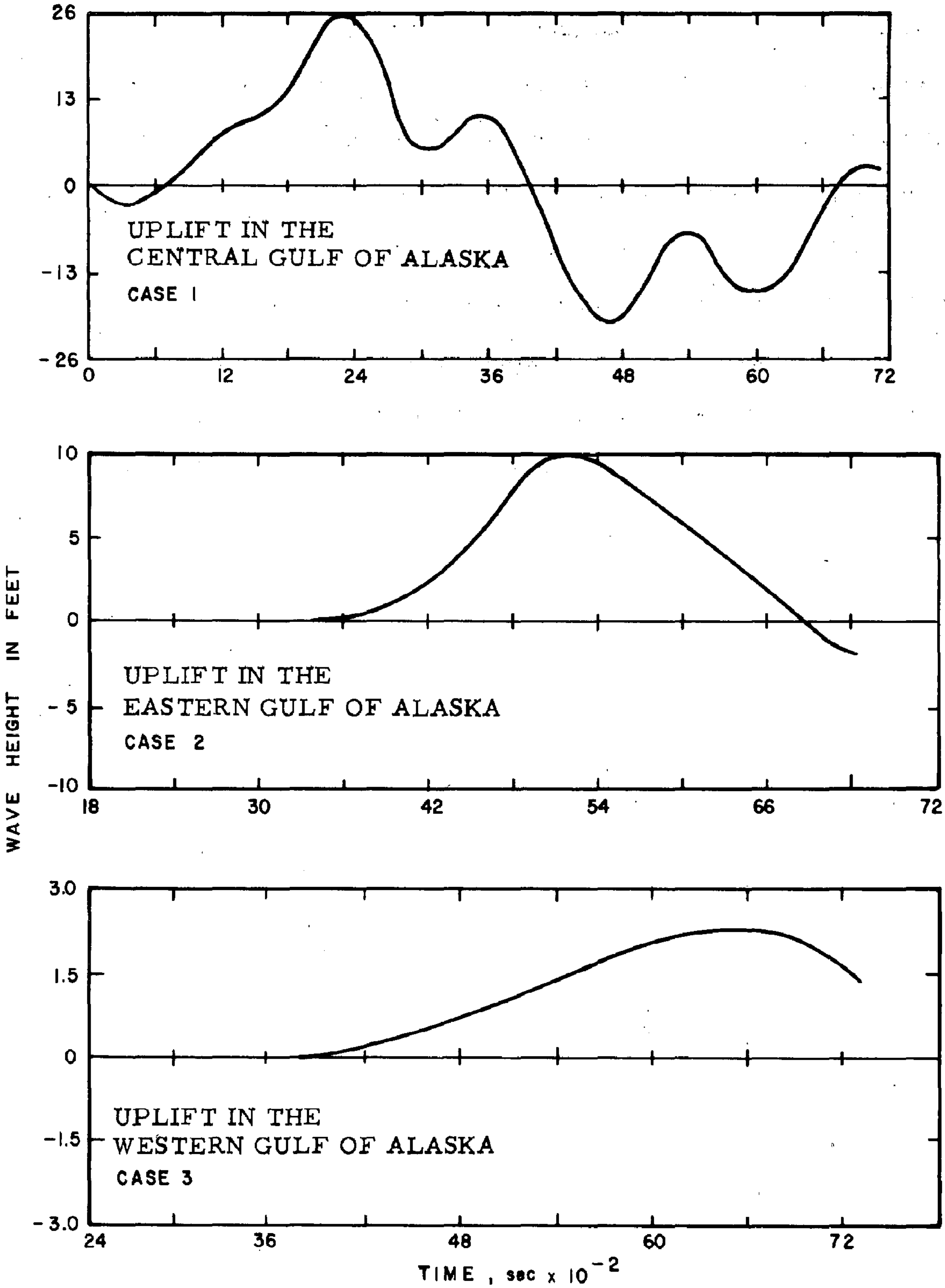

Figure 12. **Tsunami Wave Height Calculations for Seward, Alaska. (Harbor Effects Not Included)**

wavelength, and bottom topography. Under proper conditions the harbor can act as a wave height amplifier resulting in waves that are much higher than those found at nearby coastal stations. For example, the tsunami produced by the April 1946 Aleutian earthquake produced waves in Hilo, Hawaii as high as 25 feet. Yet at other locations on the Northeast Coast of Hawaii, the heights varied from as little as 10 feet to as much as 55 feet. Careful study and testing of proposed harbor sites will be necessary before predicted wave heights can be determined.

6. THE IMPACT OF NATURAL PHENOMENA ON OFFSHORE OIL FIELD DEVELOPMENT

6.1 General

Offshore Oil Field Development is divided into four phases: Exploration, Production, Storage and Transportation. The activities that take place in each phase and the equipment that is used are described in the Appendix.

Natural phenomena can cause oil spills in each phase of development. However, as was pointed out earlier, only severe storms, earthquakes and tsunamis pose serious threats. The effect of storm surges, ice, currents, etc. while important, are not likely to be critical factors in the design of structures and facilities.

6.2 Exploration Phase

Natural phenomena can be a cause of oil spills during this period by causing the drilling platform to collapse, capsize or be blown off station resulting in failure of the marine riser. If the marine riser fails drilling mud and cuttings will be released to the environment. If a formation has been penetrated, there is also the possibility that the well will blow out and gas and/or oil will be released. Back-up protection against oil spills (or other pollutants) is provided by requiring use of a Blowout Preventor (BOP) on the sea floor* and having advance warning of an impending severe natural force so that BOP valves can be actuated.

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* Usual industry practice is to place the BOP on the seafloor when floating drill rigs are used and to place it on the platform when fixed platforms (i. e. Jack-ups) are used.

Severe storms present hazards for floating and fixed platforms in both OCS areas. The threat is more severe than in the Gulf of Mexico and possibly even the North Sea. Experience to date indicates that industry has had a certain measure of success in scaling up Gulf of Mexico technology to meet the more hostile environments found in the North Sea but losses have occurred. Since 1965, there have been 10 drill rigs lost in which severe weather was either a prime or contributing factor in the loss. One of the losses (the Sea Quest in January, 1968) caused the well being drilled to go wild.

The frequency of severe storms can also have an effect on exploratory drilling. Presuming semi-submersibles will be used in both areas, the wave action will cause platform motion which in turn leads to reduced personnel performance (e.g. sea-sickness), increased rates of structural fatique failure, and increased dynamic stresses on equipment handling devices. These factors cause accidents. Prudent operation of the rig dictates that drilling operations be stopped when weather conditions exceed the operational limits specified in the design. Warning times for impending severe storms will range from about 1 hour in the Gulf of Alaska to about 24 hours on the Atlantic OCS. This can be compared with minimum warning times of 2-4 hours in the North Sea, and 24 hours in the Gulf of Mexico.

Experience with the severe storm environment in the North Sea shows that drilling operations have had to halt for weeks at a time, especially during winter periods. Semi-submersible drilling operations in the North Sea, from 1968-1971, have experienced 20% to 30% downtime attributable to weather during the months of October through March. The annual average was 14% downtime over this 4 year period. Although new construction specifically designed for Gulf of Alaska operations can be expected to incorporate lessons learned in the North Sea, it is questionable whether the drilling season can be extended and costly downtime waiting on weather reduced.

The Gulf of Alaska generally has a higher percentage of severe weather in the winter months than is found in the North Sea while the Atlantic OCS has a lower percentage. One can expect that operational downtime will be higher in the Gulf of Alaska in the winter months when compared to the North Sea. Atlantic OCS operational downtimes should be less.

Although there is usually advance warning of severe storms, there is no warning for earthquakes and local tsunamis. The threat of such phenomena in the Atlantic is quite small -- but not zero. In the Gulf of Alaska, seismic events are frequent and can be severe. Floating drill platforms are only slightly affected by local tsunamis and not at all by earthquakes. Fixed platforms, on the other hand, will be exposed to the full effects of the seismic event and their use should be carefully weighed.

6.3 Production

Almost all offshore production systems being installed today are fixed steel frame platforms. As such, they face the same natural hazards as the fixed drilling platforms used in exploration. As environmental forces have increased, industry practice has been to build bigger and stronger platforms. There is some concern within the industry that steel frame platforms can continue to increase in size and weight to meet even heavier environmental loads.* The principal objection is the rapidly increasing cost associated with the larger structures. Longer graving structures are needed during construction, expensive flotation units are required to transport the structure to the site and a major effort is needed to anchor the structure in position at the site.

These considerations are leading the oil companies to begin investment in other concepts such as concrete platforms and sub-sea completion systems. Mobil recently contracted for a concrete platform for use in the Beryl field in the North Sea at a cost of $65 million. Shell has also begun work on a concrete platform for use in the Brent field at a cost of $55 million.

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* Large well equipped platforms in the Gulf of Mexico designed to be placed in 300 feet of water and withstand 100 year winds and waves weigh about 10,000 lbs and have bases which measure about 100 x 200 feet. By comparison, British Petroleum plans to install two platforms in the North Sea which are also designed to meet 100 year storm criteria. The platforms will weigh about 48,000 lbs and require bases spanning an area 200 x 250. Since costs tend to increase in parallel with weight, a five fold increase can be expected.

The increasing cost of production platforms has led to an increase in the number of wells that a platform must service. Modern platforms are able to service 20 to 25 wells. Future platforms can be expected to be able to service as many as 40 wells or more. In the event of platform collapse each of these wells faces the possibility of blowing out and releasing gas and/or oil to the environment. Protection against blowout is provided by manual and automatic valves installed at the wellhead or on the platform and by automatically actuated and remote actuated subsurface valves installed below the surface in the conductor pipe. Subsurface valves are now required by the USGS in all new wells and, when possible, in wells that have been worked over.

The reliability of subsurface valving has been low in the past. Principle cause has been sand erosion and paraffin blockage of the valve mechanism. Following several disastrous accidents in the Gulf of Mexico in 1969, the oil industry began a comprehensive effort to improve valve reliability. Recent tests by the USGS showed reliability had improved to better than .96. Research is continuing at several Texas universities to further improve the valves to the point that even if the platform should collapse oil or gas would not be released.

Severe storms and earthquakes will be the principal hazards to platforms. Since storm forces in the Gulf of Alaska are comparable to those in the North Sea, transfer of North Sea technology, technique and experience should be possible. The more severe storm environment in certain areas of the Atlantic OCS may require that new concepts be applied in order to keep costs within bounds. The danger, however, of applying new concepts must be recognized.

As was the case for exploration, advance warning of impending severe storms will permit shutdown of well flow and provide added assurance that blowout will be prevented.

Earthquakes present a significant threat to fixed production platforms. This is especially true in the Gulf of Alaska where severe earthquakes are a frequent occurrence. Oil industry experience in the design of earthquake resistant structures is limited. Fixed platforms placed in shallow water in Cook Inlet did survive nearby earthquake of Richter 6.5 without damage. These platforms had been designed to withstand high water current and ice rafting forces and included features not feasible for use in deep water applications. More pertinent is the platform designed -- but not yet installed -- for use in the earthquake prone Santa Barbara Channel area. The platform is a 940' steel frame tower designed to withstand without failure the strongest potential ground shaking at the site.* Although the design itself is not transferable to seismically active areas such as the Gulf of Alaska, the technology is and no significant new technology should be required in order to design stronger earthquake-resistant structures.

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* A design spectrum scaled to reflect a stabilized ground acceleration of 0.5 g was used. This was the maximum acceleration that had been recorded up to the time the design work was completed and was believed to represent the maximum force that could be expected, even from severe earthquakes. Since then, greater accelerations have been recorded. Opinion is divided as to the significance of these new values in regard to the maximum earthquake that the platform can withstand. The San Fernando Valley earthquake of February 1971 produced at Paicoma Dam at ground accelerations as high as 1.0 g although the Richter magnitude was rated at about 6.6. As a check of the proposed platform design the structural response was calculated for the motions measured at the dam. The analysis indicated the structure would survive.

Earthquakes also trigger landslides and other forms of soil instability which in turn can cause a platform to collapse. Until recently, very little attention was paid in the United States to the problems of soil stability during seismic events. The extensive damage in the 1964 Prince William Sound earthquake awakened interest in this subject and research has begun. However, the state of knowledge is such that only general statements can be made regarding the minimizing of this effect. For example, sites should not be located on steep slopes or on soils having poor cohesive properties. Before the specific site is selected, an extensive test boring program must be completed to ensure the structural stability of the underlying foundation bed.

The lack of advance warning of impending earthquakes increases the risk that a major oil spill can occur. The redundancy afforded by the manual valving systems is lost. In addition, if platform collapse is due to ground slumping it is unlikely that the Christmas tree will survive. Therefore, whether oil will be spilled or not will depend entirely on proper functioning of the subsurface valve.

It is expected that all offshore sites will be located in water depths ranging from 200 feet to perhaps as much as 1000 feet. The frame construction of the platform and the depth of water in which the platform is located minimize the forces that a tsunami would exert on the structure. This is true even in the case of local tsunamis generated near the location of the platform. Finally, the wave height for even the largest tsunami that can be postulated is considerably less than the design wave height and will not top the bottom deck of the structure.

The possibility that a tsunami could occur during the passage of a severe storm was also considered. In this case the rise in water level could increase the storm wave height above that for which the structure was designed. The probability of this occurring was calculated using the techniques described in the next section and was found to be vanishingly small.

6.4 Storage

Three types of storage can be proposed for use on the OCS development: ashore storage, afloat storage and underwater storage. See appendix for a detailed description of each type. In all three cases the volume of oil per storage unit can be large. Tank sizes are rarely less than 200,000 bbls and can go as high as 1,000,000 bbls. Even larger tanks are being proposed.

Ashore storage tanks can be damaged or destroyed by flooding caused by severe storms, by the action of tsunami waves, by earthquake shaking and by loss of soil stability during seismic events. Damage from flooding and from tsunamis can be avoided by proper site location, such as is being done for the terminus of the Trans Alaska Pipeline at Valdez. The same is true for avoiding damage due to loss of soil stability. (At Valdez, the TAPS tanks will be located on bed-rock.)

The damage caused by dynamic shaking is due to the overturning moments generated by the free surface effect of the contained fluid. The overturning moments caused by sloshing liquid leads to buckling of the base ring and subsequent collapse of the structure. The possibility of damage can be reduced by minimizing the free surface effect (e.g. the use of baffles) and by installing and strengthening the foundation supports.

If damage to the tank should occur, secondary protection against oil spillage is provided by surrounding the tanks with restraining dikes capable of containing the total amount of stored oil. Ashore storage is the least likely storage system to be affected by natural phenomenon.

Afloat storage can be damaged by severe storms and, if located in shallow water, by tsunamis. In both cases the damage is due to the tank breaking free from its mooring and then grounding or capsizing. The likelihood of grounding can be minimized by requiring that the moor be located in deep water at some distance from the shoreline or shoal water. This requirement will also eliminate the tsunami threat since the nature of the tsunami wave in deep water is different. The distance will depend on the time that would be required to bring recovery vessels such as tugs to the location of the drifting storage vessel. Capsizing can be avoided by using designs based on the concept of a nearly submerged vertical spar. A 300,000 bbl storage tank using this concept will be installed by the Shell Corporation in the North Sea. The lack of an adequate containment system should a rupture develop in the tank is a serious shortcoming of this system when compared to ashore storage.

Underwater storage tanks are susceptible to damage from severe storms, earthquakes and tsunamis. The damage from severe storms are primarily due to the forces generated by the water velocity and acceleration during the passage of the waves. To mitigate these forces, one approach has been to surround the structure with an open mesh wave attenuation barrier. This system is being installed at the Ekofisk field in the North Sea. The experience gained in this environment will be valuable in adapting the design for use in other severe storm areas.

More important are the hazards associated with earthquakes and tsunamis. The dynamic shaking associated with the earthquake ground motion produces large drag and inertial forces is the bulky structure due to damping by the dense medium (sea water) surrounding the structure. For the more severe earthquakes, these forces can easily exceed the forces associated with severe storms and unless accounted for can cause damage or failure of the structure. Similiarly, loss of soil stability can produce equally serious effects.

If the structure survives the earthquake forces there are still the tsunami forces to be considered. These include the increase in bouyant force produced by the increase in mean water level, and the increase in drag forces and inertial forces especially at depth. Each of these factors will have to be considered in light of the proposed design before a development decision is made and approved.

As with floating storage, containment of oil spills will not be possible.*

To summarize, ashore storage represents the safest method of storage from the aspect of oil spillage due to natural phenomenon. Floating storage can be considered an alternate method but represents a higher risk. The problems associated with underwater storage are sufficiently great to require very careful analysis before using this method in earthquake and tsunami prone areas.

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* The Phillips Ekofisk structure has a wave attenuation barrier surrounding the storage tanks. For small spills, this barrier may be of value. It is unlikely that it would be very effective in the case of large spills.

6.5 Transportation

6.5.1 Pipelines

Pipelines are the element least sensitive to the effects of natural phenomena. Modern methods of construction, welding, coating and burial provide superior protection against severe storms, earthquake vibration and tsunami effects at the shoreline. Elaborate route selection and engineering studies coupled with seismic and test boring programs are effective in minimizing the likelihood of having the pipeline traverse areas of unknown soil properties. When pipelines must traverse fault lines or other regions of poor soil stability, a valve installation program should be developed. Check, block and pressure relief valves are installed at locations on both sides of the fault line or other unstable zone. This will minimize the amount of oil that would be spilled in the event that foundation support is lost and a pipeline break occurs.

The proposed 800 mile Trans Alaska Pipeline design is an example of the considerations that will enter into developing an adequate valve plan. The pipeline crosses three areas of high seismicity in going north to south across Alaska. Based on a thorough geologic and seismic field survey, a valving program was developed which would minimize the possibility of serious oil spills along the proposed routes. Ninety-four remote control block valves and 35 check valves are to be installed. The proposed locations of the valves would admit the maximum potential (worst case) oil spillage of approximately 64,000 bbls. This can only occur if the break is located along a segment comprising about 1.5% of the length. Along 68% of the line, the maximum that would be lost (assuming prompt detection of the break) would be less than 25,000 bbls. The expected throughput can be up to 2,000,000 bbls/day. The frequency and volume of spills from pipeline systems that would be used on the OCS cannot be predicted until site selection and route location details are determined. Nevertheless, it is reasonable to expect that large spills can be minimized and perhaps avoided.

6.5.2 Tankers

Tankers constitute one of the most serious oil spill hazards from the aspect of volume of oil at risk. Historical data on large oil spills shows that the majority of cases were due to tanker collision, grounding or structural failure caused by passage through heavy seas. Structural failure in this case could be considered caused by natural phenomena. However, in virtually every case the underlying cause can be attributed to failure to properly maintain the hull and equipment during upkeep and repair periods or failure to use prudent seamanship by either avoiding areas of severe storms or if trapped in bad weather by modifying course or speed to minimize the wave forces. Tankers that are well maintained and operated in a prudent manner should be able to avoid serious structural damage throughout their operating life.

A significantly more serious threat of oil spillage exists when a tanker is moored at a fixed berth in a tsunami prone area. Here the tanker is located in relatively shallow water (less than 100 feet and more likely only a few feet over the maximum tanker draft) where the full force of the tsunami will be felt. The forces that develop can snap mooring lines and carry the tanker ashore. In the 1964 Alaska earthquake, the Standard Oil tanker Alaska Standard moored at Seward was carried several hundred yards out into the harbor. In Valdez, the 10,000 ton freighter CHENA broke its mooring when the land slumped at the shoreline. It was carried several hundred yards away from the pier by the outrushing water and then carried back onto the mud flats by the reflected wave.

Similar occurrences have been observed whenever ships have been moored when a major tsunami occurred. As early as 1867, as a result of a tsunami that struck the Virgin Islands, the USS DeSoto was severely damaged when it struck the wharf. The USS Monongahela was carried ashore. The tsunami wave height was reported to have been 20 feet.

The problems associated with mooring in tsunami prone areas can be avoided by use of the single point moor placed in deepter water away from the shoreline. The tsunami wave forces will be less and, in the event the moor parts, the ship will have maneuvering room to regain control.

6.6 Oil Spill Probability Estimates

We have undertaken to estimate the likelihood of an offshore structure being damaged or destroyed by natural phenomena during its field life. We had hoped that this estimate could be based on the past experience of the oil industry in operating in the offshore environment. However, as we have noted earlier, the environmental conditions found in the OCS areas, especially the seismic phenomena in the Gulf of Alaska, differ enough from what the industry has had to face in the past, that estimates based on past experience would have little real value. We have, therefore, used an analytical approach that considers the design criteria and factor of safety specified for the structure, and the likelihood that a particular event would occur.

Major offshore structures are designed to withstand an environmental stress specified by the future owner or operator of the rig. The level selected has typically been the forces associated with the 100 year storm. However, regardless of what design criteria is selected there is always a finite possibility that these forces will be exceeded by one or more natural occurrences over the life of the field.* When this occurs, oil spills can result.

Based on several important assumptions we have calculated the number of times oil spills can occur due to natural phenomena. We have assumed that each severe natural occurence is independent of the others

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* Example: Over a 30 year field life there is 26% likelihood that one or more storms will pass through the area having forces greater than those associated with the 100 year storm and a 14% chance of forces greater than the 200 year storm.

and that the probability of the occurrence is small so that the Poisson distribution applies. The other important assumptions are:

1. That the probability that a natural event will occur is adequately described by the recurrence relations given in the previous sections.
2. That structural designers can develop designs that will withstand the forces developed by specific natural events (e.g. the forces associated with earthquakes having magnitudes less than 7.2).
3. That when a specific natural event occurs it will occur in the vicinity of an oil field and expose the structures to the full force associated with the event.

The duration of time that a reservoir produces oil is known as the field life. It depends on a number of factors such as reservoir volume, depth of water at the site, amortization costs and the time required to develop the field. Based on past industry practice, it is unlikely that field life on the OCS would be less than 20 years or extend beyond 40 years. Calculations were therefore made for three values of field life; 20 years, 30 years and 40 years.

6.6.1 Estimate of the Likelihood of Platform Collapse and Well Blowout

Unprotected wells can blow out if the platform collapses. As noted previously, platform collapse can be caused by storm forces which exceed the design storm, by motions associated with a nearby earthquake which exceed the design spectrum, or if the earthquake triggers loss of soil stability causing the foundation to fail.

The probability of one or more storms exceeding the design storm has been calculated for design specifications of the 100 year storm with safety factors of 1.5 and 2.0 and for 200 year storms with the same safety factors. We have presumed that when a storm of greater magnitude passes through an area the full effects will be felt by the platform (worst case).

The same approach was used in the case for earthquakes. Here it was presumed that a design spectrum could be developed for earthquakes of magnitudes 6.6, 7.2 and 8.6.* The same safety factors were used.

If a platform collapses, the conductor pipes will shear. However, the positive open control lines to the subsurface valve will also shear and the valve should close and prevent the loss of oil. As noted earlier, the valves are not 100% reliable. Recent testing showed a reliability of about 0.96 to 0.97. We have used 0.96 for our calculations.

Industry is sponsoring research to identify the failure modes of subsurface valves so that the design can be improved and reliability increased. To show what improved reliability would mean in terms of reducing the estimate of failure, we have also selected a valve reliability of 0.99 for our calculations.

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* There are a number of seismic records available that will allow the development of a design spectrum for magnitudes of 6.6 and 7.2 provided the large scale ground structure at the proposed sites is not significantly different from the areas where the recordings were made. This may be a significant problem especially in the Atlantic OCS regions and more study will be required to determine if modifications to the design spectrum will have to be made.

There are no seismic records of earthquakes having magnitudes as high as 8.3 to 8.6 although several authorities believe that one can extrapolate the data from lesser magnitude shocks. This too will require more study.

Table 11 summarizes the estimates.

As a specific example consider a platform located in one of the Atlantic OCS areas. Assume that the platform was designed to withstand the 100 year storm and has a margin of safety of 2.0. The field life will be 30 years. Then there is a 0.14 possibility (or 1 chance in 7) that storm forces will exceed the platform design specifications during the life of the field. If subsurfacing valving is installed, the chance for a blowout is .006 (1 chance in 167) for a reliability of 0.96 and 0.0014 (1 chance in 700) for a reliability of 0.99.

Examination of Table 11 illustrates several important points. First, the likelihood of platform collapse increases linearly as the age of the field increases and decreases linearly as the design storm criteria is increased. For example, a platform designed for the 100 year storm and placed in a 20 year field will have the same likelihood of failure (0.09) as a platform designed for the 200 year storm placed in a 40 year field. This suggests then that platforms planned for long life fields have more stringent design criteria specified than those planned for fields having shorter lives.*

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* Ideally, one would require the most stringent design criteria regardless of field life. However, the cost of more stringent criteria may not be able to be amortized over the shorter producing life.

Table 11. ESTIMATE OF PLATFORM COLLAPSE AND WELL BLOWOUT (SAFETY VALVE RELIABILITY - 0.96 and 0.99)

	Age of field in years			Remarks
	20	30	40	
Severe Storm Design Standard				
100 yr storm				
Margin of Safety - 1.5	.09/.0036/.0009*	.14/.0056/.0014	.19/.0076/.0019	Average number of times severe storms will cause well blowout
Margin of Safety - 2.0	.04/.0016/.0004	.07/.0028/.0007	.08/.0032/.0008	
200 yr storm				
Margin of Safety - 1.5	.05/.002/.0005	.07/.0028/.0007	.09/.0036/.0009	
Margin of Safety - 2.0	.02/.0008/.0002	.03/.0012/.0003	.04/.0016/.0004	
Earthquake design				
M = 6.6				
Atlantic M_s - 1.5	.25/.01/.0025	.38/.015/.0038	.51/.02/.0051	Average number of times earthquakes will cause well blowout
Atlantic M_s - 2.0	.23/.009/.0023	.35/.014/.0035	.46/.018/.0046	
M = 7.2				
Atlantic M_s - 1.5	.10/.004/.0010	.16/.064/.0016	.21/.008/.0021	
Atlantic M_s - 2.0	.09/.0036/.0009	.14/.056/.0014	.18/.007/.0018	
Gulf of Alaska M_s - 1.5	3.3/.13/.033	4.9/.20/.049	6.5/.26/.065	
Gulf of Alaska M_s - 2.0	2.8/.11/.028	4.2/.168/.042	5.6/.22/.056	
M = 8.6				
Gulf of Alaska - 1.5	.33/.13/.0033	.49/.02/.0049	.65/.026/.0065	
Gulf of Alaska - 2.0	.28/.011/.0028	.42/.019/.0042	.56/.022/.0056	
Combined Severe Storm and Tsunami				
100 yr storm	.001/.00004/.00001	.0015/.00006/.000015	.002/.00008/.00002	
200 yr storm	.0005/.00002/.000005	.0007/.000028/.000007	.001/.00004/.00001	

*(Platform Collapse/Well Blowout R = 0.96/Well Blowout R = 0.99)

Secondly, platforms used in the Atlantic OCS must be able to withstand the maximum earthquake that has been recorded on the Atlantic seaboard if the likelihood of collapse is to be no greater than that for severe storms during the field life.*

The third important point is that even when a platform to be used in the Gulf of Alaska is designed to withstand the maximum earthquake that has occurred (8.6 Richter) there is a three to seven times higher likelihood of collapse over field life than that for a severe storm.

Table 11 also lists the likelihood of damage caused by having a tsunami occur during the passage of a severe storm. At the outset of the study, there was concern that in the Gulf of Alaska, an area of frequent tsunamis and storms, a wave height could result that would exceed the design wave height. This was investigated and it was found that the joint probability will be considerably less than the design storm probability. As can be seen the estimates are about 1/100 of the values calculated for the 100 year storm.

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* This is not strictly so since it presumes both that there will be a dense uniform distribution of platforms over the entire OCS and that the likelihood of an earthquake is the same in all OCS areas. In fact, platforms will probably be concentrated in 6 to 10 specific areas, whereas most Atlantic earthquakes tend to be concentrated in the New England area. Both factors will reduce the likelihood of earthquake damage. The extent of this reduction will require further study.

6.6.2 Estimates of the Likelihood of Oil Spillage From Storage Systems

As stated above, storage facilities fall into three general categories: ashore storage, floating storage and underwater storage. Likelihood of failure has been calculated for floating storage and underwater storage* using the same approach as before. The results are shown in Table 12.

Consider floating storage. Storms are the only phenomena that will affect floating storage placed in deep water. The same linear relation exists between field life and more stringent design criteria. That is, if field life is doubled then the recurrence interval for the design storm should be doubled to maintain the same probability.

It is important to note that these estimates are the likelihood that a floating storage tank will break its moor and go adrift. If capsizing or grounding can be avoided and if service craft can regain control of the drifting tanks, the threat of oil spillage will be averted. One way to

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* Government regulations now require that ashore storage tanks be enclosed by sufficiently high dikes such that if the tank fails, the oil that is released will not escape from the area. We maintain, therefore, that the chance of oil spill due to natural phenomena is zero provided that the integrity of the dikes is not damaged. The integrity is, of course, very dependent on the quality of the soil foundation. It is extremely important that a thorough geologic investigation of the proposed site be made before design begins to confirm that the soil properties are satisfactory.

Table 12. PROBABILITY OF DAMAGE TO STORAGE SYSTEMS DUE TO NATURAL PHENOMENA

	Age of field in years			Remarks
	20	30	40	
Ashore	0.0	0.0	0.0	Dikes have 100% reliability against damaging oil spill
Afloat				
100 yr storm				
Margin of Safety - 1.5	.095	.14	.19	Average number of times severe storms will cause parting of Floating Storage Moor -
Margin of Safety - 2.0	.044	.066	.088	
200 yr storm				
Margin of Safety - 1.5	.047	.070	.093	
Margin of Safety - 2.0	.022	.033	.044	
Underwater				
100 yr storm				
Margin of Safety - 1.5	.095	.14	.19	Average number of times severe storms will damage or destroy underwater tanks
Margin of Safety - 2.0	.044	.066	.088	
200 yr storm				
Margin of Safety - 1.5	.047	.070	.093	
Margin of Safety - 2.0	.022	.033	.044	
Earthquake				
M = 6.6 Margin of Safety - 2.0				
Atlantic	.23	.35	.46	Average number of times an underwater storage tank will be damaged or destroyed
M = 7.2 Margin of Safety - 2.0				
Atlantic	.09	.14	.18	
Gulf of Alaska	2.8	4.2	5.6	
Tsunami				
Atlantic	.13	.20	.26	Average number of tsunamis having heights greater than 6'
Gulf of Alaska	4	6	8	

avoid the threat of capsizing is to use a spar* type floating storage. Grounding can be avoided by locating the moor position some distance away from shallow water.

The storm threat to underwater storage is equal to that for floating storage since the same design parameters are used. However, the probability of failure is increased because of the susceptibility of the storage to earthquakes and tsunamis. These factors raise the probability of failure significantly over that for floating storage. Tanks designed to withstand earthquakes of 6.6 Richter and located on the Atlantic shelf are 2 1/2 times more likely to suffer earthquake damage than storm damage during their lifetime. Tanks designed to withstand earthquakes of 7.2 Richter and located on the Atlantic shelf have an equal likelihood of earthquake damage or storm damage during their field life. If the same tanks are placed in the Gulf of Alaska, the likelihood of earthquake damage is 30 times greater.

The same comments apply with respect to underwater storage and tsunamis. Presuming that a tank can be designed to withstand a 6 foot tsunami, it is 1 1/2 times more likely that a tank located on the Atlantic Coast will be damaged by a tsunami than by a storm and 40 times more likely in the Gulf of Alaska.

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* Spar storage systems are long vertical cylinders similar to the Flip platform used for ocean research. They are very stable and experience very little motion even in heavy seas. However, since they will usually extend up to several hundred feet below the surface, it is necessary that they be moored in deep water.

Combining probabilities for all natural phenomena affecting floating and underwater storage, one finds that underwater storage located in the Atlantic is at least 5 times more likely then floating storage to be damaged by natural phenomena. In the Gulf of Alaska, underwater storage is 74 times more hazardous than floating storage.

To summarize, ashore storage represents the safest form of storage from the aspect of natural phenomena. When ashore storage is not feasible, floating storage is safer than underwater storage in both the Atlantic and Gulf of Alaska regions.

6.6.3 Estimates of the Likelihood of Natural Phenomena Damage to Transportation Systems

Pipelines that are properly designed, constructed and emplaced are relatively insensitive to all natural phenomena with the exception of ground faulting and slumping along the pipeline route. The possibility of loss of soil stability cannot be assessed until a thorough geologic analysis of the selected route is made and a valve location program is selected. These are steps which are taken during the late stages of the exploration program and follow the decision that the reservoir is large enough to make development worthwhile. For this reason the likelihood of pipeline spills due to natural phenomena (specifically earthquakes) cannot be predicted.

Table 13 provides estimates on the effect of natural phenomena on tanker moors. Assuming Valdez is selected as a terminus*, it is estimated that a destructive tsunami has a high probability of occurrence over the life of the field. On the other hand, if a deep water floating moor is used, the only threat will likely be the severe storm. In this case the probability of the moor parting is estimated to be the same as that for the floating moor. One important difference should be noted. Since the tanker possesses its own propulsion plant it can manuever and avoid danger in the event that the moor is lost.

6.7 Summary and Conclusions

Table 14 summarizes the effects of each of the natural elements, the volume of oil at risk, and the caveats regarding certain of the evaluations. As can be seen, severe storms are not regarded as a serious oil spill threat to any of the elements of the system. In the case of afloat and underwater storage the threat has been assessed as "moderate" because of the volume of oil that is at risk.

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* The only justification for this assumption is that facilities from the Trans Alaska Pipeline will be in place. In fact, the use of Valdez will probably be restricted to production areas close to Valdez Bay.

Table 13. PROBABILITY OF DAMAGE TO TANKER MOORS DUE TO NATURAL PHENOMENA

	Field Life in Years			Remarks
	20	30	40	
Tankers				
Moored to fixed berth - Valdez	.57	.86	1.1	Average number of times a destructive tsunami will occur in Valdez
Moored to Single Point Moor				
100 yr storm				
Margin of Safety - 2.0	.044	.066	.088	Average number of times severe storms will cause parting of the tanker moor
200 yr storm				
Margin of Safety - 2.0	.022	.033	.044	

TABLE 14. SUMMARY OF THE EFFECT OF NATURAL PHENOMENA ON VARIOUS ELEMENTS OF THE OIL PRODUCTION SYSTEM.

NATURAL PHENOMENA

ELEMENT		SEVERE STORM	EARTHQUAKE		TSUNAMI	VOLUME OF OIL AT RISK PER EVENT
			VIBRATION	SOIL STABILITY		
PLATFORM		SLIGHT (note 1)	SLIGHT (note 2)	SLIGHT (note 3)	NONE	500 TO 1500 BBLS/WELL/DAY
PIPELINE		NONE	NONE	SERIOUS (note 4)	NONE	10,000 BBLS OR MORE
STORAGE	ASHORE	SLIGHT (note 5)	SLIGHT (note 6)	SLIGHT (note 3)	NONE	UP TO 1,000,000 BBLS OR GREATER (note 7)
STORAGE	AFLOAT	MODERATE	NONE	SLIGHT (note 8)	NONE (note 9)	200,000 TO 1,000,000 BBLS
STORAGE	UNDERWATER	MODERATE	SERIOUS	SERIOUS	SERIOUS	100,000 BBLS OR GREATER
UNDERWAY		SLIGHT (note 10)	NONE	NONE	NONE	
MOORED-SPM		SLIGHT (note 11)	NONE	SLIGHT (note 11)	NONE (note 11)	500,000 TO 2,000,000 BBLS
FIXED BERTH		SLIGHT	NONE	NONE	SERIOUS	

NOTES:

1. Storm forces in both areas are comparable to those in the North Sea.
2. Provided earthquake resistant design features are used.
3. Provided careful soil analysis program is followed.
4. It may be possible to reduce threat by line routing over less susceptible areas.
5. Provided tanks are sited away from flood prone areas.
6. Provided free surface effect is reduced.
7. Dikes give protection against damaging oil spill.
8. Assumes control can be regained before floating storage grounds or capsizes.
9. Provided floating storage is moored in deep water.
10. Assumes regular inspections and prudent seamanship.
11. Assumes ship control is regained before grounding.

Earthquakes vibrations seriously threaten underwater storage. Whether acceptable designs can be developed that will be able to withstand severe Alaskan earthquakes, will require further study. In fact, it may be very difficult to develop designs that will withstand the relatively infrequent Atlantic earthquakes. Since such a large volume of oil is at risk in these storage systems and since containment of spilled oil will be difficult, if not impossible, earthquake vibrations have been classified "serious" threats with respect to underwater storage.

Soil stability is also a serious factor in underwater storage. Site selection can reduce the risk considerably but the threat will remain serious because of the large volume of oil at risk.

The stability of soil beds (which also includes faulting) will also threaten pipelines. Some relief may be possible by careful route planning and an adequate valve program.

Tsunamis are a serious hazard to both underwater storage and tankers moored at fixed berths. In both cases the volume of oil at risk is large. Furthermore, in the case of the tanker, the oil would be released at the shoreline, an area considered to be the most ecologically sensitive.

Several typical oil production systems have been assembled and an estimate has been made of their value from the aspect of minimizing oil spillage in each area under consideration. Table 15 lists four typical systems. Use of pipeline and ashore storage is evaluated best for both the Atlantic OCS and the Gulf of Alaska. In the Alaskan area tanker transport will be required. A floating moor rather than fixed berths represents a lesser

TABLE 15. EVALUATION OF VARIOUS COMBINATIONS OF ELEMENTS BASED ON LOWEST PROBABILITY OF OIL SPILLS

	SYSTEM A	SYSTEM B	SYSTEM C	SYSTEM D
	WELLHEAD ↓ PIPELINE ↓ STORAGE ASHORE ↓ TANKER (FIXED BERTH)	WELLHEAD ↓ PIPELINE ↓ STORAGE ASHORE ↓ TANKER (SPM)	WELLHEAD ↓ UNDERWATER STORAGE ↓ TANKER (SPM)	WELLHEAD ↓ FLOATING STORAGE ↓ TANKER (SPM)
ATLANTIC	BEST (TANKER OMITTED)		POOR	GOOD
GULF OF ALASKA	POOR	BEST	POOR	GOOD

risk of massive oil spillage.

In the event that soil conditions are such that pipelines will be exposed to unacceptable risks, floating storage may be an acceptable alternate for use in both OCS areas.

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APPENDIX A

OIL EXPLORATION, PRODUCTION, STORAGE, AND TRANSPORTATION

A-1 OFFSHORE OIL EXPLORATION

A-1.1 General Discussion

The purpose of oil exploration is to identify the amount of oil reserve at a certain potential site. Due to the high cost of offshore drilling, prior to the drilling operation some seismic and geophysical analyses are usually conducted to obtain sufficient evidence for the justification of the investment, to identify the area of relatively high potential, and to determine the most economical drilling equipment and method to be used.

The final stage of oil exploration involves: (1) to bore a hole to the petroleum reservoir, and (2) to test and estimate the yield of the explored field. If the drilled well proves to be productive, proper casing will be installed from the reservoir to the platform for production.

The most important equipment in the offshore oil exploration is the drilling platform. Adequate planning of offshore drilling operations should be done prior to selecting the platform. The platform should be designed to withstand adverse meteorological and oceanographic conditions. Risks of failure always exist because no platform can be economically designed to resist the probable maximum forces imposed on the structure by nature or by human errors such as in the case of ship collision. The failure of a platform can cause spills of fuel and drilling mud on the platform. The failure can also damage other drilling components such as marine risers, valving system and safety devices, and consequently cause well blowouts.

Major oil spills in offshore exploration have resulted from well blowouts.

To prevent such spills, blowout preventers (BOP) are installed as soon as they can be firmly secured to the condutor pipe above the mudline. BOP is an important safety device in the offshore drilling operation. Proper operation and care of this device can not be overemphasized.

A-1.2 Description of Offshore Drilling Assembly

Drilling Platforms

There are several types of drilling platforms in use. In the early offshore oil development, oil fields were located near shore at a water depth less than 300 feet. Jackup drilling platforms were commonly used. In case of already identified oil fields, fixed drilling platforms were built for the purpose of exploration as well as subsequent production. As the offshore oil development moved further out from the shore into deeper waters, semi-submersible or floating drilling platforms were designed to maintain efficient operation in more hostile environments and deeper water depths. The characteristics of these platforms are descirbed as follows:

Jackup Platform:

A jackup or self-elevating drilling platform (Fig. A-1) has hulls with sufficient buoyancy to safely transport the platform with the drilling rig, drilling equipment and supplies to the designated location. After it is in place, the entire unit is raised to a predetermined elevation above the sea surface.

Fixed Platform

A fixed drilling platform (Fig. A-2) is a space frame structure generally supported on piles complete with jacket, conductor

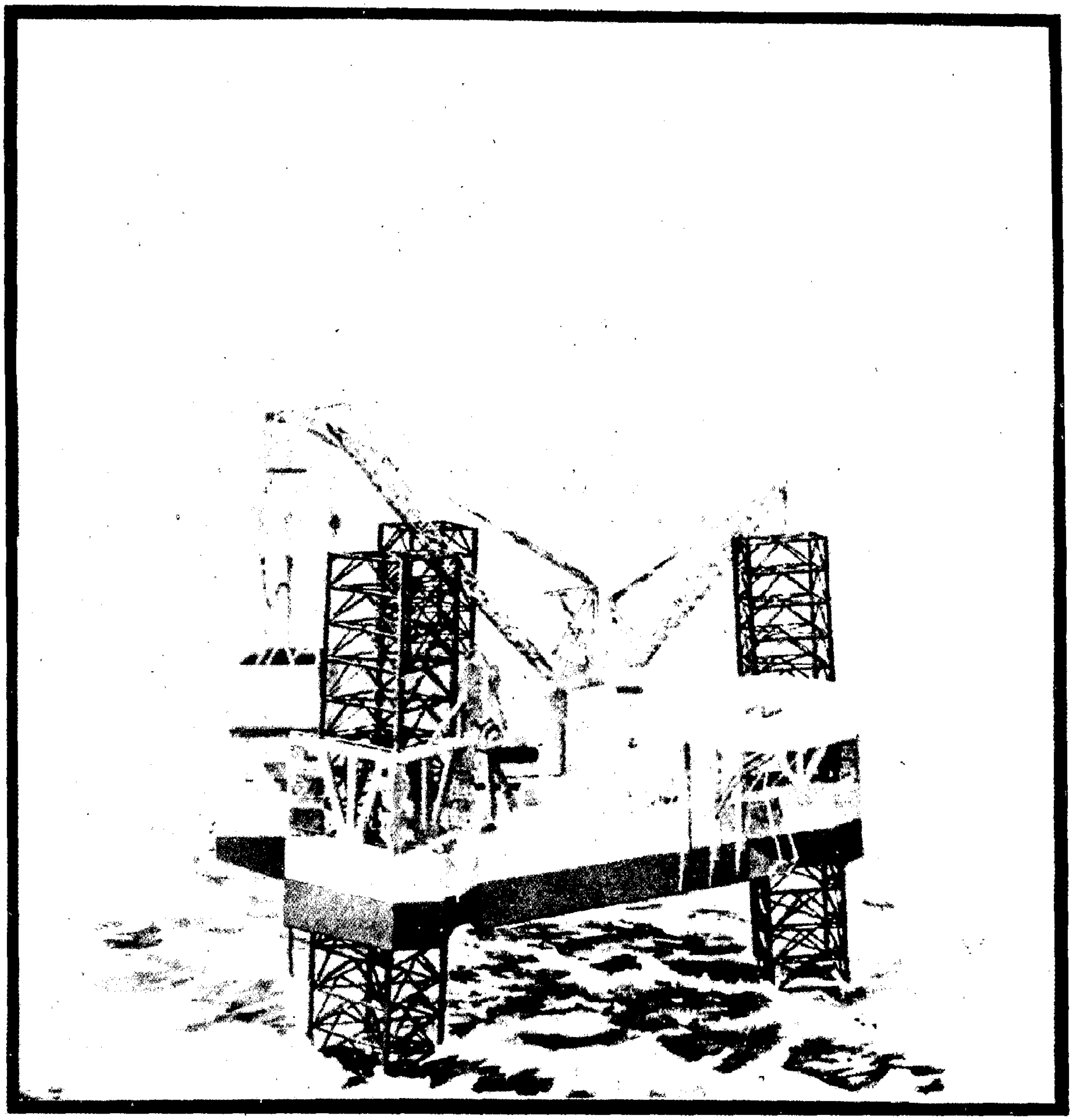

Figure A-1. A Jack-up or Self-elevating Drilling Platform. (Courtesy Zapata Offshore Company)

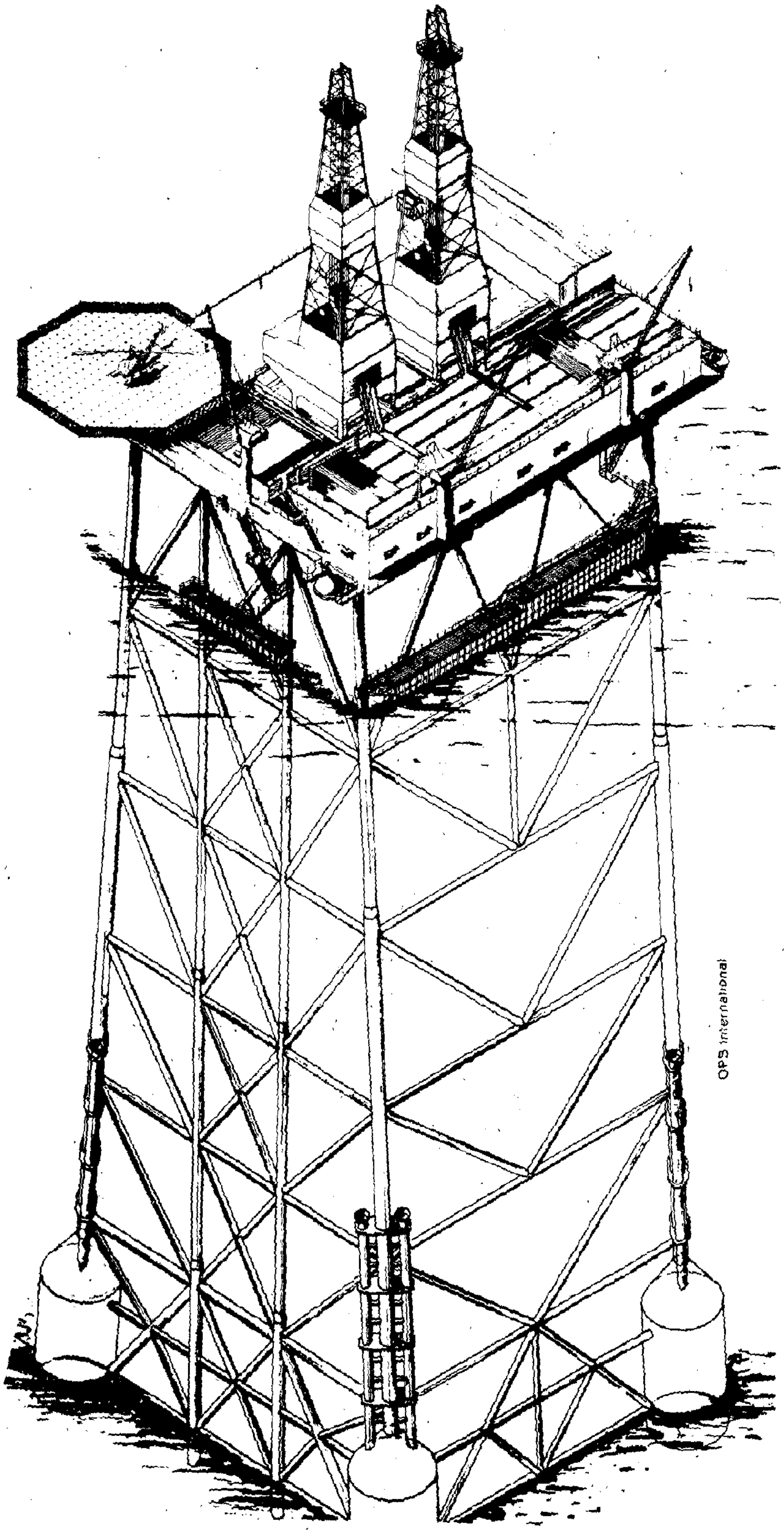

Figure A-2. A Fixed Drilling Platform. (Courtesy Interconsult) guides, boat landing, fender system, cellar deck, drilling deck, control panels and navigation aids to support the drilling derrick and equipment for drilling operation. The weight of drilling derrick and equipment is usually over 500 tons with possible hook load of up to one million pounds during drilling.

Semi-Submersible Platform

A semi-submersible drilling platform is self-contained and is supported by either lower displacement type hulls or by large caissons (Fig. A-3). Similar to the floating type drilling rig, the entire mechanical and automation design is aimed at the requirments of deep sea drilling operations. A semi-submersible drilling unit should be able to perform the drilling operation either in a floating condition or at rest on the bottom.

Floating Platform

A floating drilling platform is either a ship type or a barge type seagoing drilling unit (Figure A-4). The unit usually has a safe hull, strong mooring system and high performance propulsion units (no propulsion machinery for barge type drilling unit) and reliable stability.

A-1.3 Piping System

The piping system is usually installed prior to extensive drilling operation. The system (Fig. A-5) consists of a conductor pipe, a blowout preventer and a marine riser. The conductor pipe, normally 30" in diameter, is driven into the ocean floor to hold back the soft muds below the sea bottom.

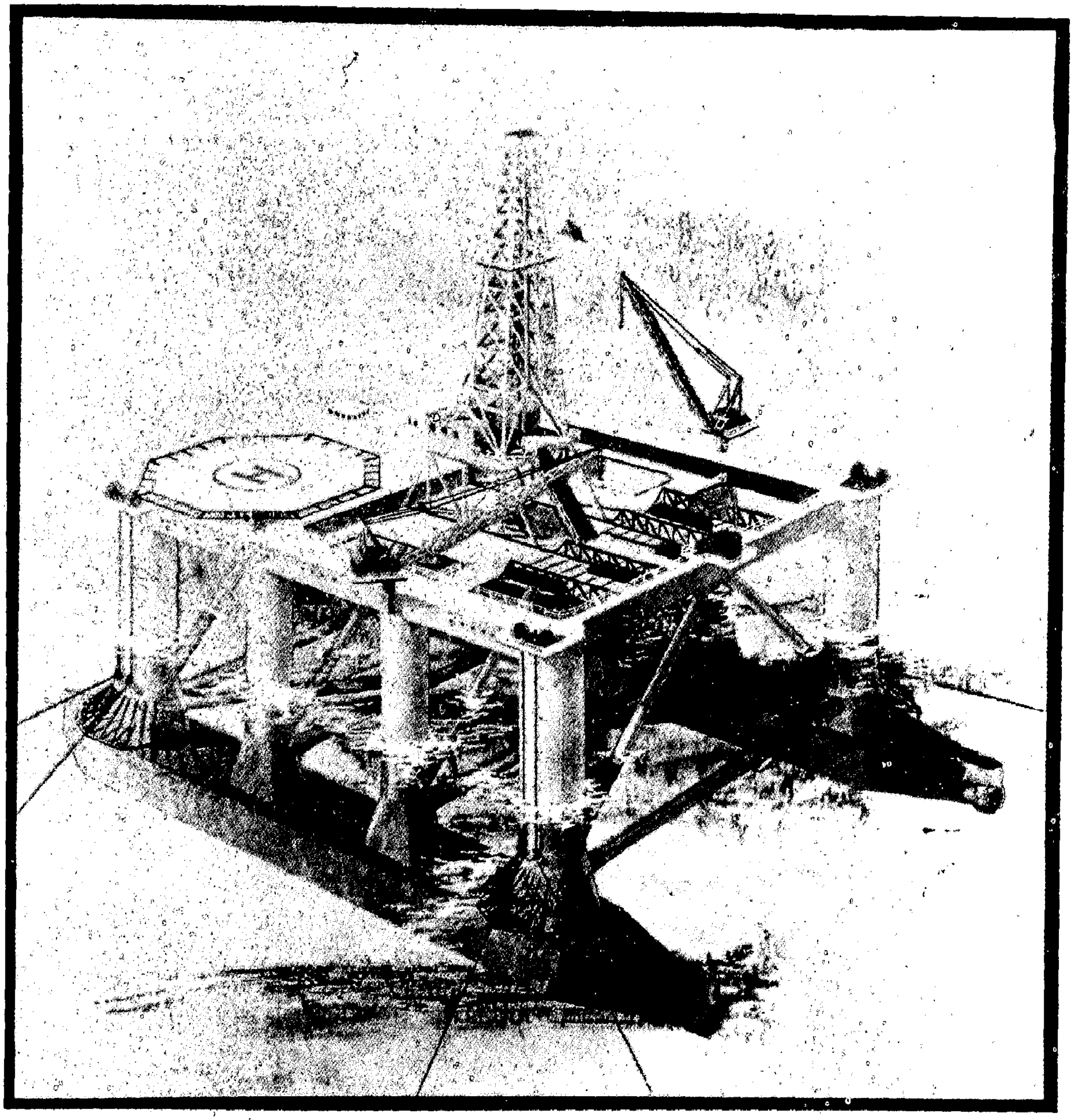

Figure A-3. Aker H-3 Semi-Submersible Drilling Platform (Courtesy Aker Group)

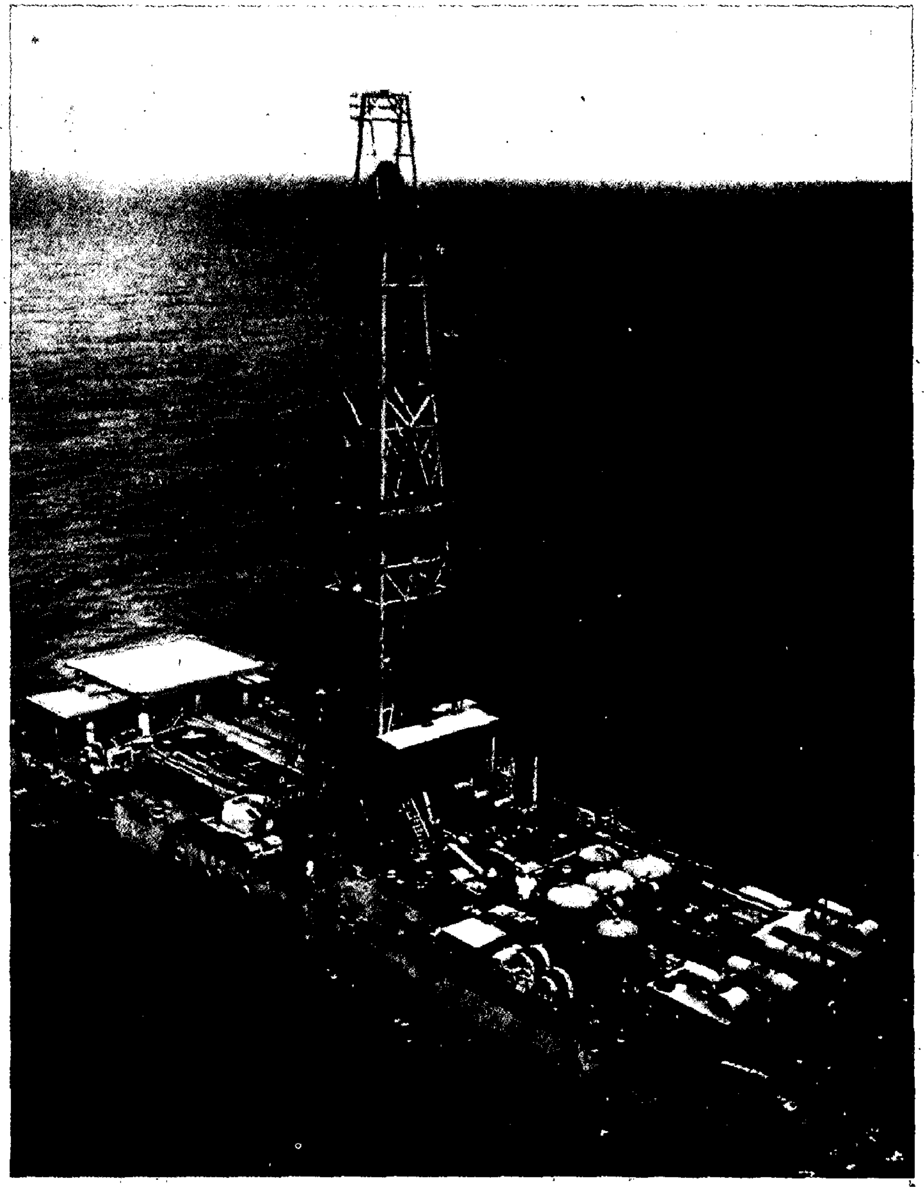

Figure A-4. Floating Barge-type Drilling Platform.

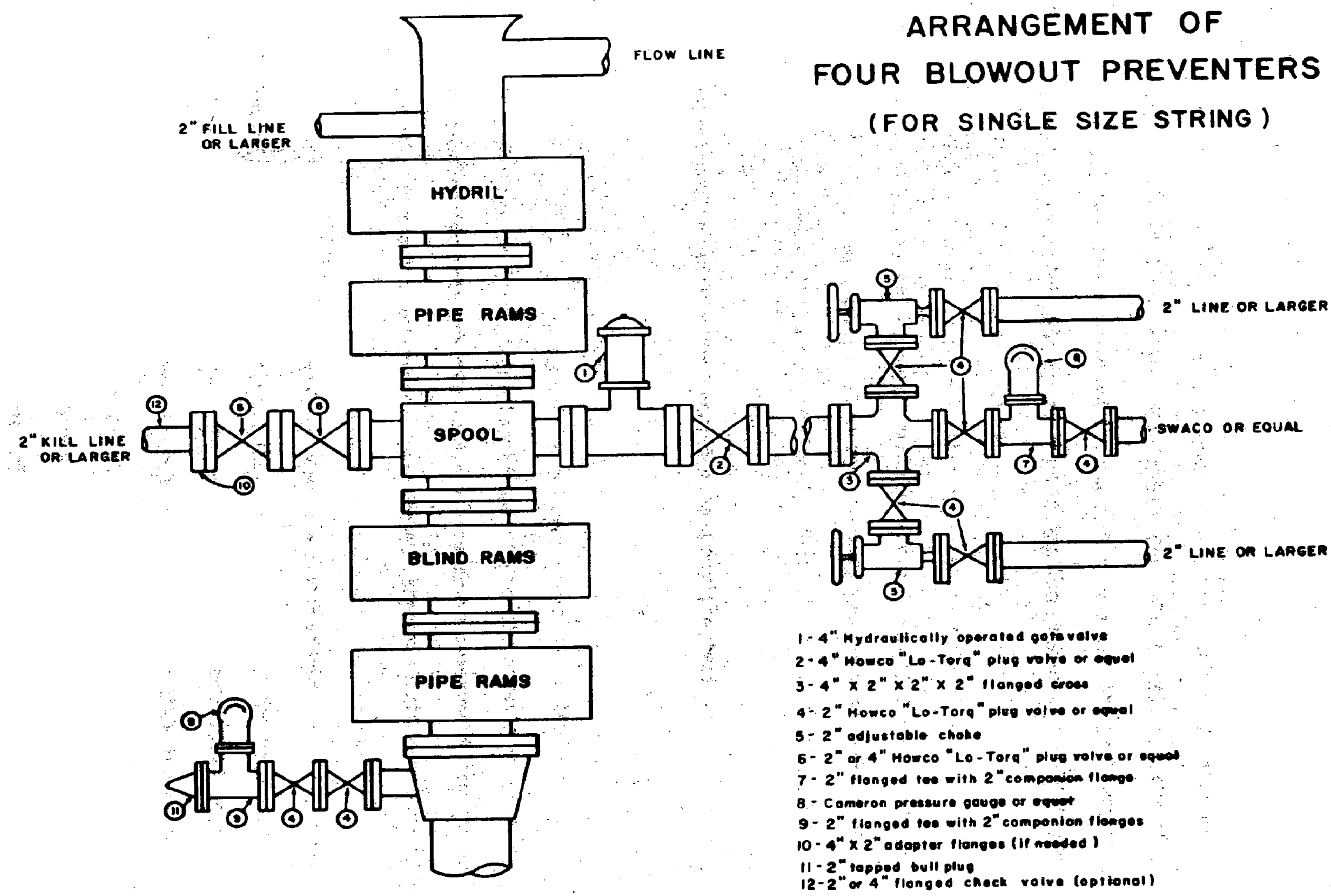

Figure A-5. Typical Blowout Preventer Arrangement.

A blowout preventer is a mechanical device designed to prevent accidental well blowout. Usually the blowout preventer stack contains two or three blowout preventers. On the very top of the blowout preventer is a spool onto which the marine riser is connected. A hydraulic connector on the lower end is for attachment to the conductor pipe.

The assembly of a marine riser consists of pipe, ball joint, connector, telescoping joint and bell nipple to furnish access to the well and to return drilling fluid to the mud tank. The marine riser must be strong enough to withstand the fluid pressure in addition to wave and current forces.

A-1.4 Preparation of Well for Production

After the oil reservoir is reached, the electric logs, cores and other information will be studied to determine the potential yield of the well. Casings of various sizes and wall thicknesses and lengths must be carefully calculated and scheduled in accordance with the formations and pressures. A typical casing string is to use 20.0" diameter pipe to a depth of about 1,000 ft.; 13.375" diameter pipe to about 5,000 ft.; 9.625" diameter pipe to 10,000 ft., and finally 7.0" diameter pipe to the desired depth.

Upon the completion of the casing installation and cement grouting, the well can be either temporarily closed off by a sub-sea wellhead assembly with blowout preventers and removable riser system, or put into production by the installation of a Christmas tree. The main function of the Christmas tree is to connect, control and manifold the oil stream from the well.

A-2 OFFSHORE OIL PRODUCTION

A-2.1 Production Platform

Following the drilling and completion of one or more wells, the exploratory drilling rig is removed and replaced by a production platform. The platform is a frame structure mounted on the sea floor and attached by a system of pilings. The platform contains various separation facilities that are used to process the flow from the reservoir. It also has a drilling platform and all equipment necessary to drill new wells or to work-over old ones. Modern platforms are able to serve 20 to 30 wells and it can be expected that later platforms will be able to handle more.

The oil from the reservoir enters the well tubing through a section of perforated tubing, and is transported to the surface where it is either gathered with the output from several other wells or is carried directly to the platform for separation. A typical production well installation is illustrated in Figure A-6. Safety valves are installed below the mud line, on the sea floor, and on the platform. These valves either operate automatically or can be remotely controlled.

On reaching the platform the oil undergoes several processes before it is transferred for storage or shipment. The processing includes separation of the gas and water from the oil stream; removal of the hydrogen sulfide, carbon dioxide and sulfur dioxide; dehydration of the hydrocarbons and desalting of the retained brine.

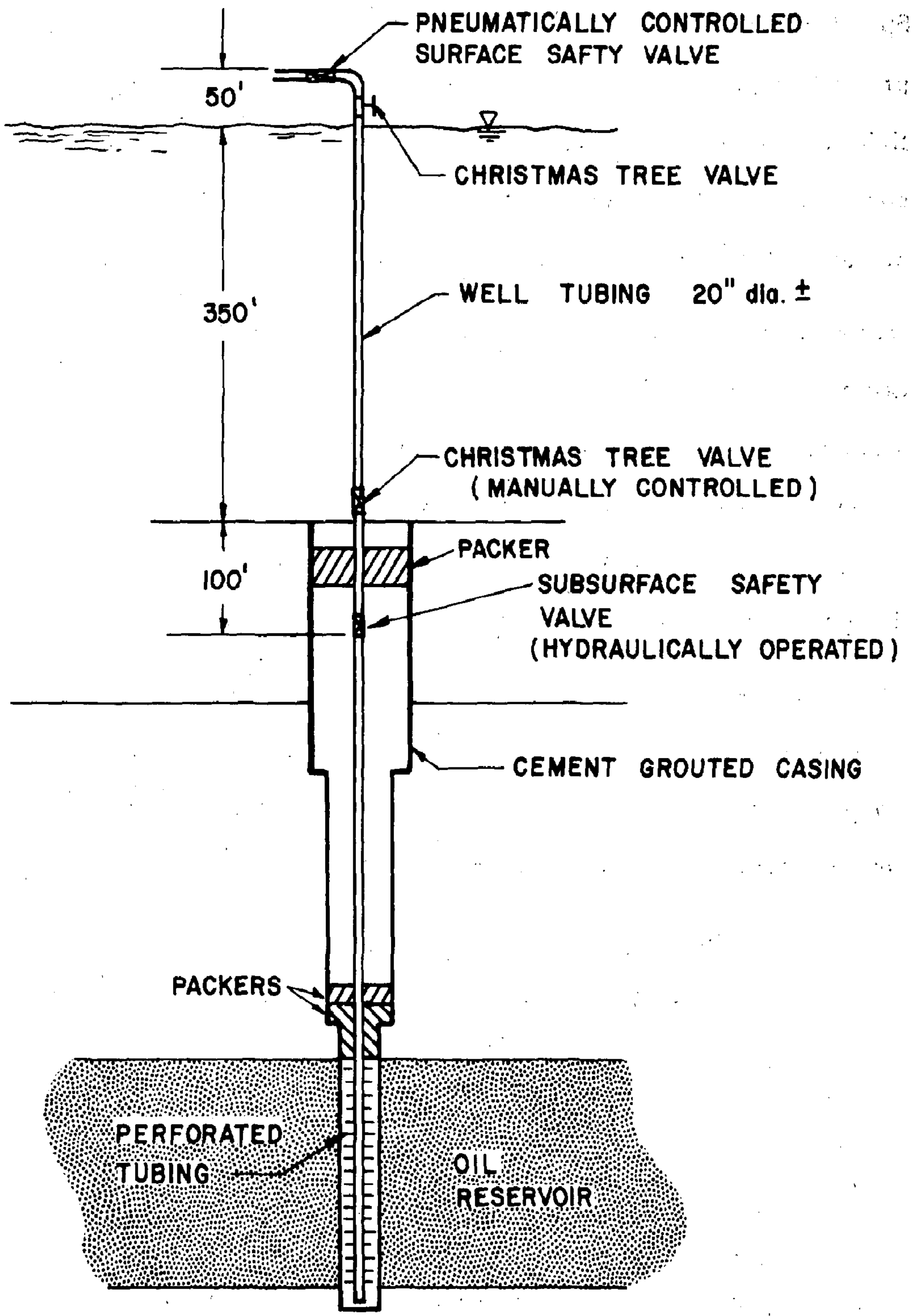

Figure A-6. Typical Production Well Installation.

Specific natural phenomena design standards are not prescribed for production platforms. The American Petroleum Institute has established recommended design practices and specifications that include consideration of various natural phenomena and it appears that designers are strongly influenced by these recommendations.

Usual design practice is to specify a capability to withstand without damage a specified design level. To ensure against platform collapse a certain safety factor is added. Where severe storms are the critical factor, practice has been to specify the 100 year storm with a margin of safety of 1.5. When other phenomena have governed the design, such as current forces, the same recurrence interval is used.

There has been only one production platform specifically designed to withstand earthquakes. This is the 940' platform proposed by EXXON Corporation for use in the Santa Barbara Channel, a moderately active seismic ares. Three criteria were specified as follows:

> <u>Criterion 1</u>
>
> Structural damage must be avoided in the event of ground shaking for which there is a significant probability of occurrence during the life of the structure.
>
> <u>Criterion 2</u>
>
> Safety against collapse must be provided in the event of the strongest potential ground shaking (or ground shaking having an extremely small probability of occurrence); plastic straining and moderate yielding are permitted.

Criterion 3

> The structure must have sufficient ductility to undergo plastic straining without loss of structural integrity. (This condition insures ductile behavior well into the yielding range).

The Margin of Safety varies, often depending on the location where the platform is expected to be placed. Margins of 1.25 to 2.0 have been used, usual practice being to specify 1.5.

USGS OCS regulations now require that subsurface safety valves be installed in each flowing well. The purpose of these valves is to shut off the flow in the event that control of the well is lost (a blowout occurs). The valves are of two types. In the older type (Figure A-7) the velocity flow type, the valve closes when the velocity of the flow exceeds a predetermined value. These valves are seriously affected by paraffin buildup and sand erosion and have displayed a low reliability in past applications.

The second type of subsurface valve is the remote actuated valve (Figure A-8). These valves are generally positive open valves and will close if the hydraulic pressure is lost. While more expensive than the simpler velocity flow valves the reliability appears to be much better. The use of this valve is expanding.

In addition to the subsurface valves it is becoming common practice to place positive open remote actuated valves on the Christmas tree at the sea floor surface, adding additional protection against well blowout.

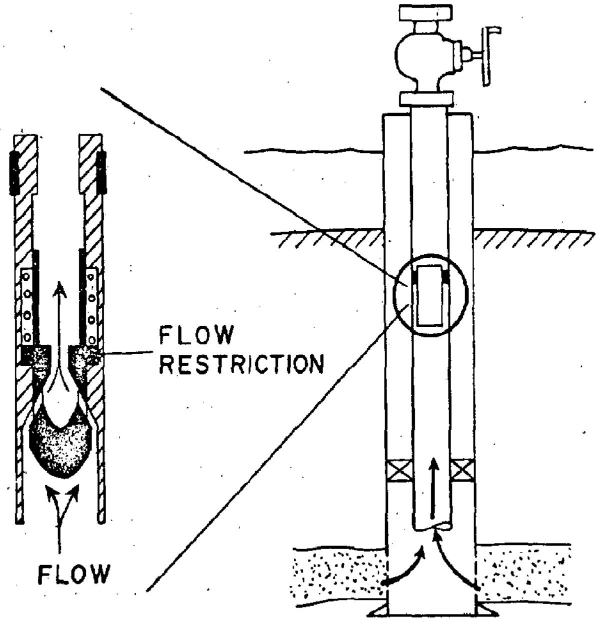

Figure A-7 Velocity Flow Controlled Subsurface Safety Valve.

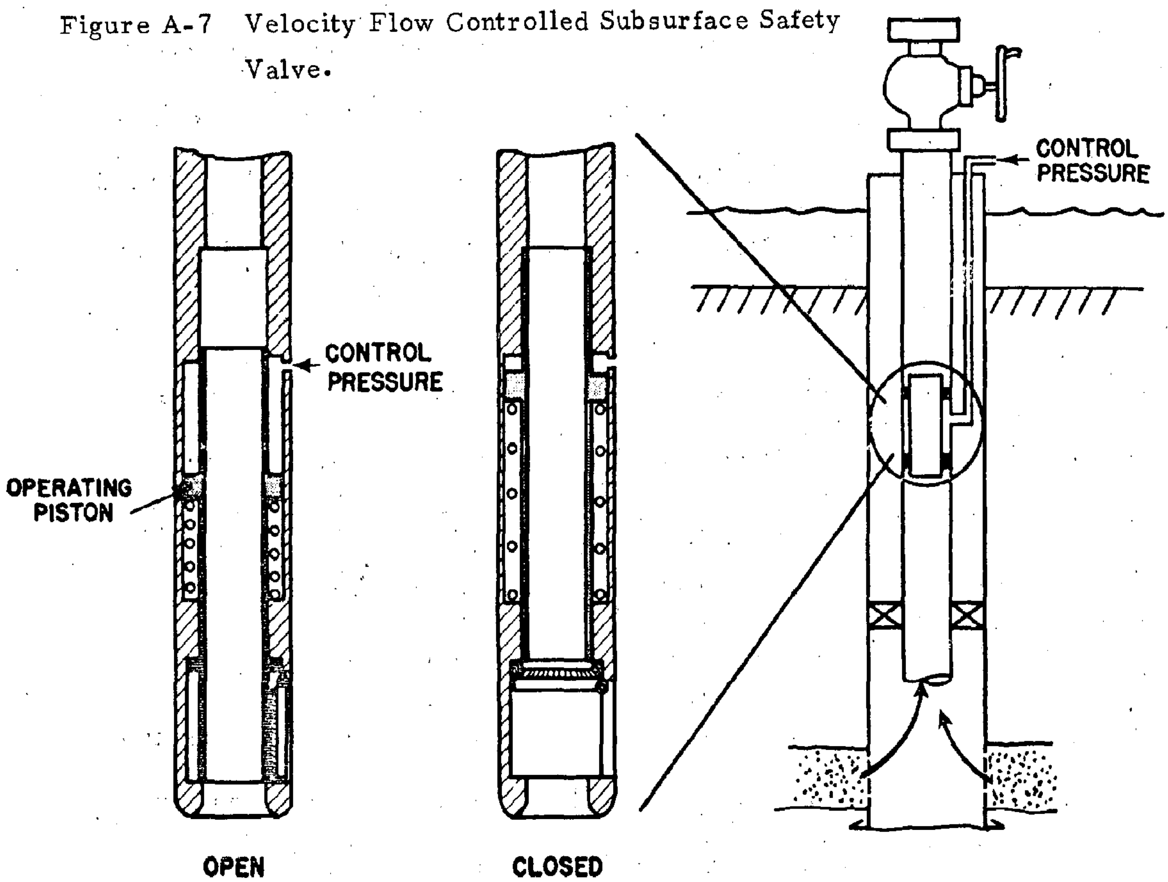

Figure A-8 Surface Controlled Subsurface Safety Valve.

The reliability of subsurface valving has received considerable attention within the oil industry over the last several years. The API has recently established recommended design, installation and testing criteria to further assure reliable operation and lessen the well blowout problem.

A-3 STORAGE

Storage Tanks are divided into three categories; ashore storage tanks, floating storage tanks, and underwater storage tanks.

The cylindrical ashore storage tanks represent the most numerous, by far, of storage tanks today. They are found throughout the world in all areas where liquids have to be stored before shipment or use. They are extremely simple in design, consisting essentially of a cylindrical steel wall that resists the outward fluid pressure, a thin flat bottom plate that rests on the ground and prevents the fluid from leaking out and a thin roof plate that protects the contents from the atmosphere. They last for years.

Natural phenomena do not appear to play a critical role in the design of ashore storage tanks. Calculation of wind loading effects and siting of the tank above predicted flood water levels have been the most important. However, as a result of earthquake damage to filled oil storage tanks, the need to include protection in active seismic areas is being recognized.

This protection consists of locating tanks on structurally sound soil beds (e.g. on bedrock), providing strong ground attachments for the bed plate and reducing the free surface effect of the contained liquid through the use of baffles.

Further protection against oil escape is provided by regulations that require that containment dikes be erected in oil storage tank areas. Current regulations limit the number of tanks within a dike perimeter to two. The dike height must be sufficient to contain the total volume of oil stored in the tanks.

Floating storage tanks have also been in use for a relatively long period of time. The earliest types were simply barges or other hull types which were moored in the vicinity of the producing wells and then towed to refineries or trans-shipment points. Several barges in use today can store up to as much as 1,000,000 bbls of production.

As would be expected, the use of barge or hull type carriers is limited to areas where severe storms are infrequent. Use in other areas exposes them to the possibility of capsizing, broaching, or being driven aground by the action of the wind and waves.

To make use of the advantages inherent in floating storage in severe storm areas, development has been underway on systems that are less affected by the wind and wave action of the storms. One of these types is the SPAR developed by Shell Oil. This concept can withstand much more severe environments than conventional floating storage vessels but retains the advantage of being able to be used in deep water environments and can be moved from location to location as the need arises. A 300,000 bbl tank is scheduled for installation in the North Sea's Brent Field. No details on the severe storm design criteria that was used are available.

The final type used in oil production is the underwater storage tank. Typical of these are the Chicago Bridge and Iron Co. 500,000 bbl inverted hemispherical tanks being used in the Persian Gulf (Figure A-9). The tank has no bottom and operates on the water displacement principle. It is always full, either with water, with oil, or a combination of both. When filled with water it has slight negative buoyancy. When filled with oil it has slight positive buoyancy.

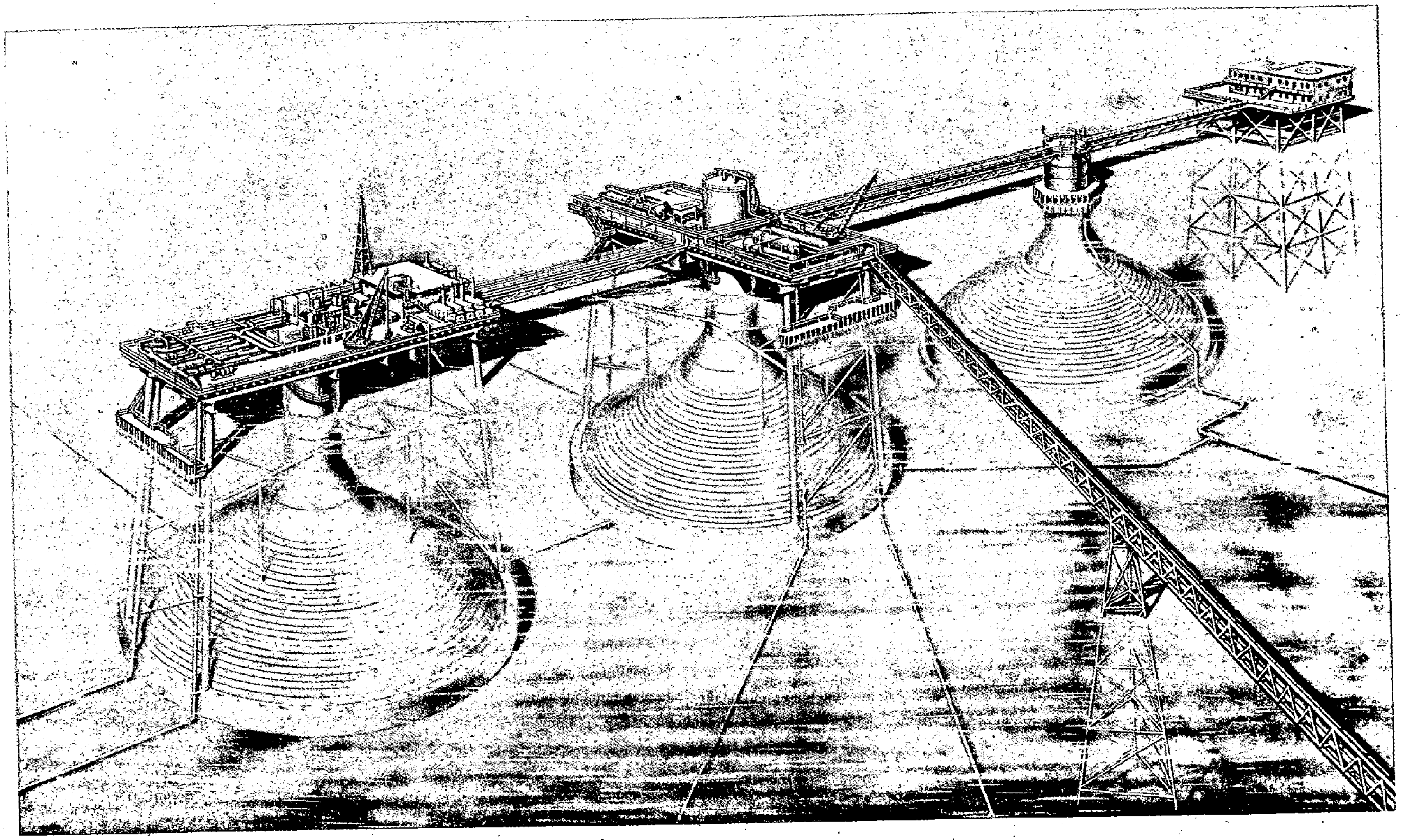

Figure A-9. Chicago Bridge and Iron 500,000 bbl Underwater Storage Installed in the Persian Gulf.

The tank is 270 feet in diameter, over 205' high and weighs 15,000 tons. The design maximum wave height was 39.0 feet and the period was 10.5 seconds. This is equivalent to the 100 year storm wave in the Persian Gulf. A safety factor of 2.0 was included.

For the more severe storm environments found in the North Sea, Phillips developed the Ekofisk storage tank (Figure A-10). This 1,000,000 bbl tank contains 9 compartmented tanks placed in a nearly square 175' x 175' enclosure 295' high. The tanks are enclosed by a 302' x 302' x 269' perforated outer wall whose purpose is to protect the inner tanks against the adverse wave conditions in the North Sea.

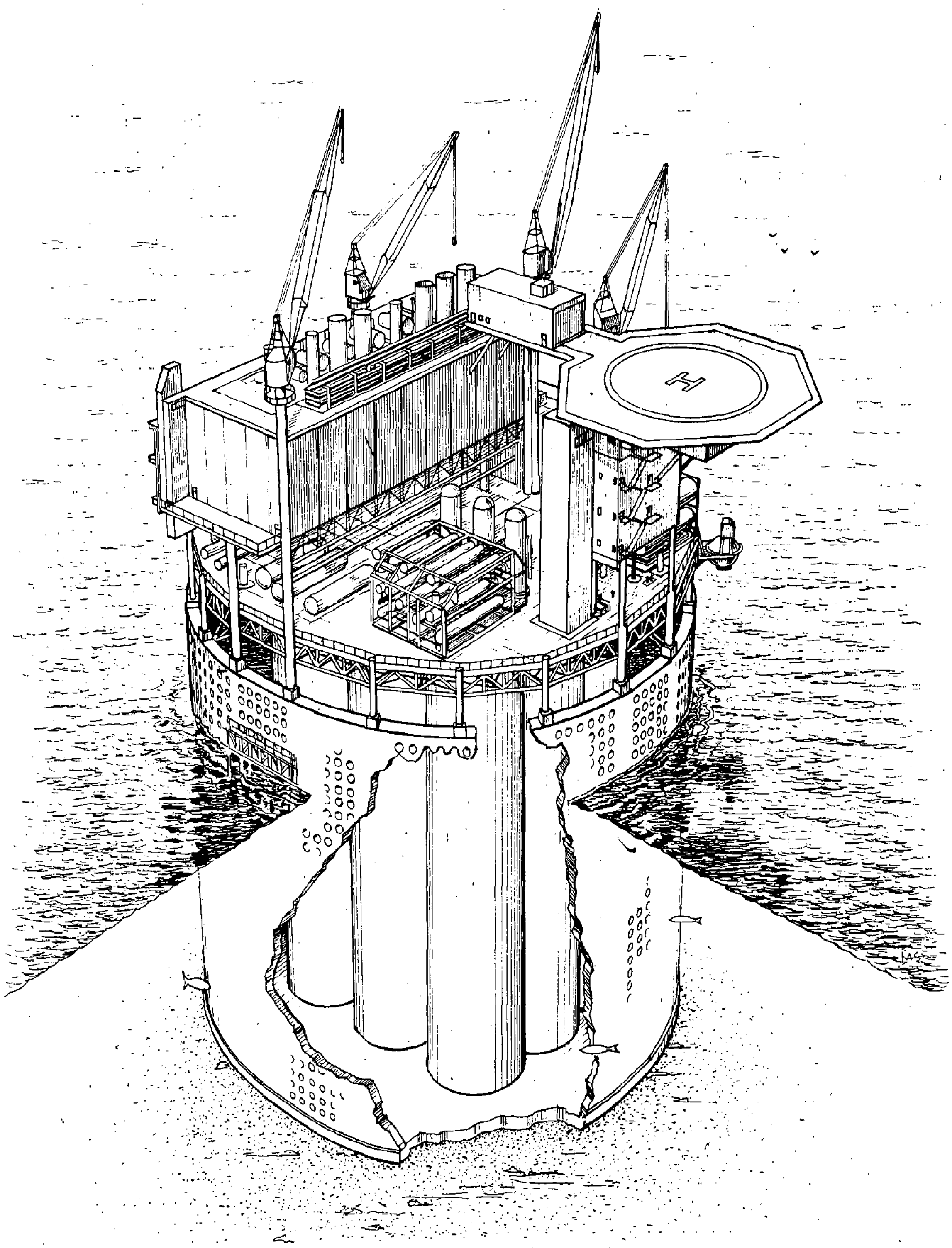

Figure A-10. Phillips Petroleum Underwater Storage Being Installed in the North Sea.

A-4 TRANSPORTATION

A-4.1 Pipelines

As a means of transportation, pipelines have been used for carrying liquids for centuries, for carrying gases for decades, and for carrying solids for years.

Oil Pipelines

The main use of pipelines, has been by the oil industry. There are vast networks of pipelines presently in use for collecting crude oil from the oil fields of Texas and Oklahoma, and from wells offshore Louisiana and Texas. These pipelines carry the crude oil to the refineries of the South, Southwest and Middle West. A similar pattern of pipelines collects oil from West Coast wells and delivers it to regional refineries.

The basic design objectives of pipeline systems are: (1) integrity of the structure, (2) minimum disturbance to the environment, and (3) economical construction and maintenance. The second two considerations are sometimes in conflict. In conventional engineering, maintenance is considered together with initial outlay to arrive at the least over-all costs, but the increasing requirements for environmental protection modifies this concept considerably. Design is based on supplemental industry codes and governmental regulations.

Once the route had been determined and the quantity of oil to be pumped (the throughput) selected, the next step is to select a pipe size and compute the oil pressures required to move the oil over ridges and to overcome wall-friction. Then a pipe material is selected to suit the ambient temperatures to be expected. The various forces that act on the pipe, and the properties of the pipe steel determine the pipe size and wall thickness.

The field joints between the pipe sections are vital. These are best made by electric arc welding which makes the pipe solid from end to end. Rigid specifications exist and thorough inspections are required to ensure a high quality seam in compliance with regulations.

External corrosion is known to cause leaks in buried pipelines. Considerable effort is expended to provide coatings which will eliminate corrosion. On the Alaska pipeline a pipe coating of an epoxy compound sprayed as a powder onto the heated metal is being used. On contact, the powder melts and the drops coalesce into a thin, tough, continuous coating to keep water from the metal. Rigorous tests are made to be sure that there are no holes in the coat. Following installation, field tests are made to determine if any small holes exist in the coating that would lead to rusting of the steel. Such double protection is the best system yet known for protection against corrosion.

Internal pipeline corrosion is recognized as being a significant cause of pipeline structural weakening and requires continued special attention. Pipeline systems are periodically sampled and monitored for internal corrosion activity. Internal corrosion is most active in low throughput systems or those that operate intermittently permitting corrosive water to accumulate in the low points of the piping system. In these instances, use of corrosion inhibitors has proven effective to prevent corrosive damage to the pipe. If internal corrosion damage is suspected to have occurred, in-line pipe inspecting instruments are available to assist in appraising the extent of pipe damage.

Valves along the line are an essential part of the system. Three main kinds are usually used: the block-valve, usually remotely controlled, which is a vertical sliding gate, capable of stopping flow of oil in either direction; the check valve, a simple flap device which automatically stops reverse flow downhill on an uphill stretch of the line; and the pressure-relief valve to protect against excessive surge, or other, pressures; this also operates automatically. Valves are essential in pipeline testing, isolation of a pump station from the line, isolating sections for maintenance, and, for controlling flow in case of a leak.

A-4.2 Tankers

Tankers constitute the final element of the transportation system. Within this category are included the great supertankers used in international transshipment of oil as well as the small tank barges used to transport oil from offshore production and storage facilities to nearby refineries.

No unique set of tanker characteristics exists and no worldwide standards govern the design. They come in all sizes, carrying capacity, and speed capabilities. A sample of tankers in operation today are given in Table A-1.

No specific tanker design standards exist although the recommended design practices and specifications of the American Bureau of Shipping

TABLE A-1 TANKER CHARACTERISTICS

Ship Size (dwt)	Length, Overall (Feet)	Beam, Overall (Feet)	Draft, Loaded (Feet)	Speed (Knots)
60,000	775	105	40.5	16.5
80,000	820	122	43.0	16.5
100,000	891	128	47.0	16.5
120,000	924	128	52.0	16.0
150,000	945	150	57.0	16.0
210,000	1,066	155	62.0	16.0
250,000	1,141	170	66.0	16.0
325,000	1,135	175	81.5	15.7

provide valuable guidance during the design period. Coast Guard rules and regulations are also carefully followed.

Current design practice is to specify a design wave having a wave length equal to the ship's length and then calculating the hull sag and hull hog when the ship is posed crest to crest and trough to trough respectively. The wave height that is used is selected by the designer and is some function of the wave length. One that is often used is a wave height that is 1/20 of the wave length. For the 1000' class of supertankers this is roughly equivalent to the 100 year wave in the Gulf of Alaska.

Tankers age rapidly in the environment to which they are exposed. Twenty years appears to be a representative concensus of efficient tanker operating life. Beyond twenty years maintenance and repair requirements make tanker operations become highly inefficient. Furthermore, studies show that tanker physical life rarely exceeds 30 years.

As the tanker ages the probability of hull failure increases. This factor must be taken into account in assessing the capability of the tanker to withstand severe storms.

The tankers can be loaded in several ways. In the first the tanker is moored to a wharf or a pier. Oil is pumped to the tanker from storage tanks, through a set of loading hoses into the tanks of the ship. Automatic cut-off valves are provided in the event there is an accidental disconnect of the hoses from the tanker.

In the second case, the tanker moors to a single buoy which contains an oil riser and manifold. Several buoyant hoses are run from the manifold to the tanker. Oil is pumped from either ashore storage, underwater storage, or floating storage. This system also has valving that shuts it off automatically should the hose become disconnected from the tanker or the buoy.

Toward Resolving Problems in Outer Continental Shelf Technology

Table of Contents

[Note: Part III, Commissioned Panel Papers, and Part IV, Supplementary Papers, are not reproduced here.]

PART I. CONFERENCE BACKGROUND AND SUMMARY

BACKGROUND OF THE CONFERENCE

Even before the unprecedented action of the Organization of Petroluem Exporting Countries (OPEC) in late 1973 in using oil exports to the oil-deficient industrialized nations as a political weapon, it had become obvious that the imbalance between domestic oil and gas production and consumption in the United States would continue to grow larger. Reducing energy consumption through conservation practices can reduce U.S. dependence on imported oil supplies but will probably not eliminate them in the next few years.

A second, and perhaps more important, action of the OPEC nations started in 1970 and rose to a crescendo in the fall of 1973. This was the sharply increased prices of OPEC oil exports which jumped to a level five (and even higher) times the historic price levels that had prevailed during the decade of the 1960s. These large price increases have provided an even greater incentive to develop domestic resources for both security and balance-of-payments reasons. Also, by setting world prices at such high levels additional petroleum and natural gas resources that would not have been considered economic to develop can now justify exploration and development investments.

Large quantities of oil and gas resources still remain to be discovered onshore and on the Outer Continental Shelf (OCS) of the United States. The amount that remains to be found is subject to wide differences of opinion, varying by a factor of 5 between the highest and lowest estimates. Even the lowest estimates of remaining resources projects that more oil will be found than has been discovered to date, so that accelerated domestic oil and gas exploration should result in increased domestic oil and gas production and a reduction in the amount of oil that would otherwise be imported.

The favorable onshore petroleum provinces of the United States have been well explored and, until new exploratory techniques are developed, new discoveries can be expected to be more difficult to make and to be at ever greater depths. On the other hand, exploration has taken place on only a small fraction of the OCS lands, and some major potential new provinces--the Atlantic and Gulf of Alaska OCS lands--have not been drilled at all.

Although the OCS represents the most favorable areas for finding the much needed domestic oil reserves, its development has many environmental hazards associated with it. Offshore drilling has been practiced on a small scale for many years but the increasing depth of water in which wells are being drilled, their much larger numbers, and the need to transport the oil onshore where it can be used create a much greater probability of oil spills, with their attendant potential for environmental damage.

The experience of the U.S. petroleum industry operating offshore California and in the Gulf of Mexico has, overall, been very good. However, the incident at Santa Barbara and several spectacular fires on offshore platforms have focused public attention on whether the state of OCS technology is sufficiently advanced so that exploration and production on the OCS should be allowed to continue, or whether new technologies must first be developed--particularly for new provinces with their different sea, seismic, and meteorological conditions. This widespread attention and concern about the OCS environment is simply another indication of the growing public awareness and of its desire to see that environmental values are preserved.

At the first sign that favorable geologic conditions existed for petroleum provinces offshore the Atlantic Coast, many inhabitants of these coastal states and their political representatives immediately became concerned about whether these new provinces could be developed with acceptable environmental risks. This raised questions of the adequacy of existing OCS technology if it is to be used under the different sea, meteorological, seismological and ecological conditions that exist in the Atlantic and Gulf of Alaska areas as compared to the Gulf of Mexico and offshore California areas for which the technology had been developed.

In an effort to answer these and other major issues about the costs and benefits of offering offshore leases in the Atlantic and Gulf of Alaska,[1/] President Nixon, in his April 1973 Energy Message to Congress, asked "the Chairman of the Council on Environmental Quality (CEQ) to work with the Environmental Protection Agency, in consultation with the National Academy of Sciences and appropriate federal agencies, to study the environmental impact of oil and gas production on the Outer Continental Shelf and the Gulf of Alaska." As a part of its program to carry out this Presidential mandate, the CEQ requested Resources for the Future to hold a conference on OCS technology which would (1) evaluate the current status of technology and its applicability for use in the new provinces being considered for leasing, (2) estimate the degree of risk of environmental damage from the application of current technology to the areas, and (3) identify improvements, if any, still required in OCS technology to operate with acceptable environmental risks, and the R&D required to achieve them. RFF was not requested, nor did it attempt, to evaluate whether improved technology, effluent taxes, or other methods--or combinations of them--would be the preferred route for reducing environmental risks.

1/ Resource availability, regional supply and demand alternatives, primary environmental effects, potential effects of onshore development and OCS management issues.

METHODOLOGY OF THE STUDY

At the time of the CEQ request, two authoritative studies had already been published on the state of OCS technology. The first, Outer Continental Shelf Resource Development Safety,[1/] was authored by a Panel on Operational Safety in Offshore Resource Development of the Marine Board of the National Academy of Engineering (NAE) and published in December 1972. The second report was prepared by an interdisciplinary team of the University of Oklahoma (OU) and was designed to make a technology assessment of OCS development. It was entitled Energy Under the Oceans--A Technology Assessment of Outer Continental Shelf Oil and Gas Operations[2/] and was published in September 1973.

Using these two studies as the basic documents around which to organize a conference, RFF examined the various steps involved in OCS development. In order to divide these functions into manageably-sized units that could be studied, seven discrete groups of activities were identified. It was recognized that the OCS development is actually a continuum of operations that necessarily overlap and that some duplication was inevitable as a result of the arbitrary groupings that were selected. The seven topics chosen were exploration, field management, drilling, production, transport and storage, containment and cleanup of oil spills, and fire prevention and fire fighting. Of these seven topics, four were thought to be still controversial with

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1/ National Academy of Engineering Marine Board, Panel on Operational Safety in Offshore Resource Development, Outer Continental Shelf Resource Development Safety: A Review of Technology and Regulation for the Systematic Minimization of Environmental Intrusion from Petroleum Products, PB 215 629 (Springfield: National Technical Information Service, December 1972).

2/ Don E. Kash, et al., Energy Under the Oceans: A Technology Assessment of Outer Continental Shelf Oil and Gas Operations (Norman: University of Oklahoma Press, 1973).

respect to the state of technology and where it could be safely used, and two of them--drilling and production--were the most controversial of all.

The three topics on which the literature in general, and the NAE and UO reports in particular, showed no important differences among the experts were exploration, field management and fire prevention and fire fighting. As a result, the conference did not hold panel sessions on these topics but papers were commissioned on each. These were prepared by personnel of the U.S. Geological Survey (USGS) and are included in this report. The opinions expressed on these topics in these papers and in the NAE and UO reports are included in the overall conclusions and recommendations of this report.

For the other four topics (drilling, production, transport and storage, and containment and cleanup), two papers were commissioned on each which were designed to identify differences between the NAE and UO reports on their assessments of the state of technology and, to the extent possible, to suggest methods of reconciling them. These commissioned papers were to be used as the basis for the panel discussions at the conference. One other report was used (although it was received just before the conference began) in both the panel discussions and in the preparation of the final panel reports. This was entitled North Sea Oil and Gas[1] and was prepared by five of the eight University of Oklahoma personnel who authored the earlier UO report.

Four parallel sessions were conducted, one on each of the four topics identified as needing further discussion. Three sessions were held on drilling and production, and one session each on transport and storage and containment and cleanup (see Agenda at the end of this section).

1/ Irvin L. White et al., North Sea Oil and Gas: Implications for Future United States Development (Norman: University of Oklahoma Press, 1973).

In a final joint session of all the participants, the Chairmen and rapporteurs presented preliminary reports of each of the panel deliberations.

Attendance at the conference was by invitation and a deliberate attempt was made to have articulate representatives of differing viewpoints and constituencies attend. Thus, representatives of the National Academy of Engineering Marine Board, the University of Oklahoma, industry, the various government agencies (U.S. Geological Survey, U.S. Coast Guard, Environmental Protection Agency, National Aeronautics and Space Administration, Atomic Energy Commission, National Oceanic and Atmospheric Administration, Maritime Commission), environmentalists, and other informed members of the public all participated.

The draft reports of the rapporteurs of the sessions were reviewed by the respective panel members and their suggestions included wherever possible. Reservations on a given part of the rapporteur's report by panel members are included as footnotes to the panel report wherever the comments received were of sufficient importance to warrant this treatment. The panel reports do not attempt to reach a consensus where one was not reached, but rather identified differences that could not be reconciled. The reports, however, do make specific recommendations with respect to the adequacy of various techniques for leasing on the OCS of the Atlantic Coast and Gulf of Alaska, even in the absence of a consensus, and could not have been incorporated in the revised version of the report without, in fairness to the panelists, resulting in another round of reviews.

WORKSHOP OVERVIEW

It has proved to be very difficult to (1) arrive at a factual and accurate assessment of the status of the various OCS technologies in producing provinces and their applicability to the sea, meteorological and seismological conditions that will be found in new provinces, (2) assess the environmental risks that the transfer of this technology will entail, and (3) determine if new technology is necessary to operate at an acceptable risk level in the new areas. There are honest differences of opinion about the state of technology and about the many facets of this complicated system. There are also uncertainties in defining and estimating risks. Beyond problems arising from differing technological assessment, obtaining agreement among the parties involved is extraordinarily complicated by several obstacles.

The first obstacle is a threshold question. Who is entitled to participate in the dialogue? It is clear from the background papers, but emerged even more sharply as an issue in the panel discussions, that industry generally believes that it possesses the expert knowledge, has had long-time experience and is investing _its_ money in these developments and should be allowed "to get on with the job." Its representatives seem to argue that those outside the industry who are attempting to participate have little to contribute to solving the problems that have emerged, may be unnecessarily slowing down development, are sometimes demanding safeguards beyond those which are reasonable and which the industry is sufficiently motivated to adopt in its own interest, may be encouraging unneeded additional regulation, and may bring about incorporation of backup safety measures that have unfavorable cost/benefit ratios.

Those members of the public who have concerned themselves with these matters[1] argue, on the other hand, that the resources being developed are of national concern, that not all of those operating on the OCS are using acceptable or "best available" technology, and that the industry may be willing to take environmental risks that at least some of the public think are unacceptable, in the sense that in evaluating the costs and benefits industry may, at times, either ignore or improperly assess costs that are external to their business interests.[2]

This clash over who should be involved and in what way is most clearly reflected in the panel reports on drilling and production. It appears in a much less obvious form in the transport and storage report, and is least obvious in the containment and cleanup report. The different degrees of involvement of the various panels in this question could have been predicted. The drilling and production accidents have produced the spectacular events that aroused the public to the problem, so it is in this area that industry has felt the most pressure but it is also nearly the only source of knowledge of how to improve the technology. Transport and storage have also been the source of some oil spills but they are generally not as eye catching as those produced by drilling or production accidents, or as spectacular as platform fires. It was, and should have been, difficult for industry to argue against public participation in containment and cleanup activities, since this is a subject which is germane only when an accident or spill of some kind has already occurred.

1/ Hereafter the word "public" will be used to include those other than representatives of industry. It is also recognized that only a small part of the total public has become active in the question of OCS leasing.

2/ Privately, of course, both members of the industry and the public may take even stronger stands on the issues.

A difference in attitudes of industry and the public members of the workshop also emerged in a related area. The public members were generally urging that industry turn to other disciplines for help in solving some of the OCS problems. They emphasized the concept of viewing the problems in the context of a system made up of the man and the machine. Since many of the accidents have been human rather than equipment failures, it was argued that the use of people trained in the behavioral sciences could be of great help in improving training and in designing equipment that would reduce human error. Although industry has already taken steps in some areas to apply such knowledge where it is more obviously useful, it still resists acknowledging that the industry should use such non-petroleum disciplines and knowledge on a routine basis.

The second major obstacle to reaching agreement is the industry's fear of government encroachment on its activities. This industry attitude toward government involvement in its operations is of long standing and industry has resisted consistently and vigorously efforts of government to enlarge its requirements in every area where government and the petroleum industry interface. The present energy shortage has brought to the fore a variety of proposals to open up to public view the large domestic petroleum companies so that their representatives are now particularly sensitive to suggestions that would result in more regulations of OCS operations. This problem, too, was most clearly highlighted in the Drilling Panel where suggestions for stricter USGS inspections, for government certification of platform workers, for inspection and certification of training schools, and for government R&D, at least in some areas, were met with some industry opposition.

The panel reports seem to suggest a third obstacle to obtaining agreement on the issues with which the workshop was confronted. This was related to the rapidly changing state of technology, regulation, and industry and public involvement in the OCS. In spite of its concern about external intervention and government regulation, in order to move forward and to improve its performance industry has rapidly developed new technology and responded to the pressures placed upon it by the emerging concern of the public about the environment. As experience has been gained in new areas where different problems were encountered, new technology tailored to the given physical parameters was developed. As environmental enhancement became of greater interest to the public, the industry devoted greater attention to preventing accidents and reducing spills. The governmental response has taken the form of more comprehensive standards and more regulation by the government to see that the standards are enforced. These rapid changes have given the critics of the industry a difficult moving target since frequently their suggestions have been incorporated into use before they are even aware of it.

While the improved equipment that has been developed and the better operating procedures that have been introduced will undoubtedly reduce accidents and spills in the long run, it is the growing awareness of industry, government and the public of their respective roles and the need to work together that could be of even greater importance. So many of the suggestions for improvement in OCS operations that were contained in the working papers for the panels have already been applied widely that the evidence is clear that rapid progress has been and is being made in improving all aspects of OCS operations. In spite of the sharp differences that emerged--and that were discussed above--about "whose problem is it" and "how much regulation is too much," the industry is responding, as it always has, to the changed ground rules. It is obvious that in the future there will be greater public participation and more regulation, and the industry will want to cooperate so as to insure that demands placed upon it are both reasonable and technically feasible.

Consensus was reached on many of the issues that were discussed; for these, see the individual panel reports. Some of the specific remaining differences and the panels' conclusions are given below.

SUMMARY

Drilling Technology

Some Remaining Differences

1. Whether existing monitoring and recording devices are sufficient to reduce blowouts to environmentally acceptable levels, and whether there is merit in increased automation.

2. Whether mandatory training and/or certification should be required for the operators and whether government should set and enforce training standards.

3. Of what value would be the reporting of "near accidents."[1]

4. The amount, nature and type of public participation that is justified in the method for the setting of standards and the regulation and management of OCS activities.

5. The extent to which the drilling industry relates to, and could benefit from, non-petroleum technologies.

1/ The Production Panel reported that the failure-reporting system of the type suggested by NASA is working well and has resulted in improved performance.

Conclusions

1. Despite some specific improvements that can still be made, no problems were identified as being significant enough, in the drilling phase, to warrant abstention from extending activities to new areas.

2. There should be a designation of a lead agency within the Federal regulatory structure, a tightening up of regulatory activities, the establishment of a regulatory regime that can be counted on for some years, and industry should be given as much lead time as possible when government expects to lease in new areas.

3. Industry still remains generally hostile to what it considers intervention by the public untrained in OCS problems and technology and additional regulations. Nevertheless, such public participation in such activities is now provided for by law and industry must accommodate to this new condition. Additional regulations will inevitably come because some operators will not use even minimal safeguards unless required to, and in the evaluation of risk/benefit relations the public and the industry may legitimately estimate both different risks and benefits, so that the public must participate to protect what it perceives to be its interests.

4. Certain areas, especially in the environmental field, were recommended for governmental R&D funding.

Production Technology

Some Remaining Differences

1. There is some question by one panel member as to whether the best available equipment, particularly that developed abroad, has been applied promptly in the U.S. OCS operations. This is a reflection of the difficulties that arise in an area where technology is changing rapidly (see p. ____).

2. While the industry's statement put forward in the Production Panel that using Los Angeles Codes for seismic design of platforms should result in an earthquake-safe platform was not contested by other panelists, no probability statements could be made about such a platform after it is completed. (In view of the reservations expressed on this matter in the Drilling Panel by a CEQ expert, this point should receive additional consideration.)

3. No agreement was reached on what the effects of oil spills had been on the ecology in existing areas although industry representatives felt that few or no effects could be identified. These differences among the participants arose from a lack of knowledge of baseline conditions and cannot be resolved until these are determined much more accurately than they have been to date.

4. There are differences of opinion about the degree of safety of operations on a platform (particularly during workover operations) as the number of wells per platform is increased.

5. The adequacy of USGS regulations and enforcement procedures was questioned as was the need for increasing public participation in OCS activities.[1/]

6. The training of manpower and their licensing or certification was also an unresolved issue.[2/]

7. Despite conclusion (1) below, some members of the public proposed that in new areas the environmental standards should be more rigorous than the existing standards until more experience is gained in these areas.

1/ See "Drilling--Some Remaining Differences," item 4, p. 11.

2/ *Ibid.*, item 2.

Conclusions

1. With respect to environmental loads, the panel found that while some environmental conditions are not clearly known the "reasonable" worst case conditions[1/] can be met through appropriate design and operation.

2. It was concluded that technologic solutions exist for the transfer of structures (configuration, materials and fabrication, foundations), water treatment, safety valves and general sensor systems to meet levels of existing environmental standards (in the Gulf of Mexico) in the new areas. No significant needs exist for developing new technology if Gulf of Mexico environmental protection standards are acceptable.

3. More stringent standards and criteria could be met since there is still room for technologic improvement and further development may be desired or required.[2/]

4. Technology management could be profitably further developed through improved training, quality control engineering, human factor and man/machine engineering and regulatory engineering.

Oil Spills and Containment

Some Remaining Differences

1. The most serious difference that remained among the panelists was how often environmental conditions in some new areas would be so severe so as to prevent existing mechanical containment and recovery systems from operating satisfactorily and whether accidents are more likely to occur during those

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1/ USGS would be expected to regulate closely so as to assure this.

2/ The Drilling Panel also arrived at a consensus that more R&D was needed. Additional R&D was recommended by the Transport and Storage Panel, and even greater emphasis was placed on R&D by the Oil Spills and Containment Panel. The Drilling Panel, in addition spent considerable time on the role of government R&D.

extreme periods of sea or meteorlogical conditions. The industry representatives thought the conditions in which equipment would not operate occurred only 20 percent of the time, and that accidents were not more likely to occur during those periods. In contrast, one public representative said environmental conditions varied from area to area, and in some, nonoperability 40 percent of the time would be a more accurate value.

2. The Coast Guard representative had more reservations about the present and future potential of chemical dispersants for oil spill cleanup than others on the panel.

Conclusions

1. The main thrust of the panel's recommendations is that R&D in a variety of containment and cleanup processes is still needed. Examples are studies of the movement and trajectory of oil on the surface under various conditions, a knowledge of the chemical and biological processes that take place when oil is added to the marine environment, the need to develop containment and recovery devices for a wide range of sea and weather conditions testing of various devices in actual field operations, and the development of nontoxic dispersants.

2. The present techniques for containment and cleanup can be used in the OCS off the Atlantic Coast and the Gulf of Alaska a certain percentage of the time, but exactly how much in different areas could not be agreed upon. The R&D suggested in the first recommendation, if successful, could greatly increase the percentage of time when such systems could be successfully used.

Transport and Storage

Some Remaining Differences

1. With extensive U.S. experiende in overland and offshore pipeline transport, the industry feels that it has demonstrated overall integrity of pipeline systems and that prevailing practices can be transferred safely to new areas. Some public members expressed strong reservations about the adequacy of present methods in view of what they allege are large volumes of oil that have been released from pipelines. The issue is clouded by a reporting system that is widely conceded to be woefully inadequate. Moreover, the ecological system in new areas may need more rigorous standards if it is to be protected adequately.

2. Some public members thought that U.S. experience with storage has been so slight under environmental conditions similar to the OCS off the Atlantic Coast or the Gulf of Alaska that few firm conclusions should be drawn about this technology.

3. There remains some difference of opinion as to the depth of water in which pipelines of various diameters can be laid using proven technology, and whether the optimism of the industry members that they have the "demonstrated ability" to lay large diameter pipe in 900-foot deep water is justified.

4. There also remains some difference of opinion as to whether there will be increased environmental risks as pipelines are laid at greater depths. The industry states that the greater financial investments will induce greater safeguards while some public members argued that the increased costs could be a disincentive to greater safety. A public member thought there was a need to develop improved methods of monitoring corrosion of offshore pipelines and to develop improved pipeline repair techniques.

Conclusions

1. The panel concluded that adequate pipeline trenching technology exists to avoid such problems (in populated coastal zones) as spoils disposition near shore, dispersion of settled industrial wastes, etc., but that improved jurisdictional arrangements, better land use planning, and overall management decisions and appropriate monitoring are required. Except for these bothersome problems, the technology generally appears to be adequate for new areas.

2. If storage and transport are to be used in the Gulf of Alaska, the types of storage used in other areas will not be satisfactory. Floating structures designed to safeguard against rupture would be needed. This is an area where some new R&D efforts could be very useful.

3. The panel recognized the need for more complete and systematic reporting practices on pipeline leakage.

* * * * *

As can be seen from the above panel summaries, in all of the four panels there remained unresolved differences about the exact state of much of the technology, how closely the sea, weather, and seismic conditions on the OCS off the Atlantic Coast and in the Gulf of Alaska resemble those of the producing areas in which experience has already been gained, and in the evaluation of what degree of environmental risk would be involved in transferring available equipment, technology, and operating experience to the new areas. However, the panels concluded that if adjustments were made in design of equipment to take care of the identifiable differences between the new areas and the old (particularly seismic and tsunami occurrences), if more attention were paid to human factors and training, and if the regulatory function were given to one lead agency and carried out diligently by it, leasing could go forward in the OCS off the Atlantic Coast and Gulf of Alaska. The panels also noted that despite the vast improvements which have already been made by industry initiative and action in equipment design and operating techniques and by government in strengthening the standards and regulatory functions, much more can, and should be, done to continue to improve the record through R&D as well as by administrative actions.

A G E N D A

RESOURCES FOR THE FUTURE, INC. CONFERENCE ON
OUTER CONTINENTAL SHELF TECHNOLOGY AND CONTROL

DATE: December 5-6, 1973
PLACE: Marriott Twin Bridges Motel, Arlington, Virginia

Wednesday, December 5, 1973

10:30-11:00

OPENING SESSION
Joseph L. Fisher, Resources for the Future, Inc.
Stephen J. Gage, Council on Environmental Quality

11:00-12:30

SESSION 1. DRILLING TECHNOLOGY
Chairman: George F. Mechlin, Westinghouse Research Laboratories
Rapporteur: Hans H. Landsberg, Resources for the Future, Inc.

Authors: W. F. Allinder, Texaco, Inc.
"American Petroleum Institute Comments on the Three Conference Background Studies"

A. J. Laborde, Ocean Drilling and Exploration Co.
"The State of Offshore Drilling Technology, With Special Reference to the Gulf of Alaska and East Coast"

SESSION 1. PRODUCTION TECHNOLOGY
Chairman: Ira Dyer, Massachusetts Institute of Technology
Rapporteur: Frederick Wells, Resources for the Future, Inc.

Authors: E. O. Bell, Mobil Oil Corporation
"Environmental Protection Technology in Offshore Petroleum Completion/Production Operations"

C. C. Taylor, Exxon Company, USA
"Status of Completion/Production Technology for the Gulf of Alaska and the Atlantic Coast Offshore Petroleum Operations"

2:00-5:30

SESSION 2. DRILLING TECHNOLOGY
Chairman: George F. Mechlin, Westinghouse Research Laboratories
Rapporteur: Hans H. Landsberg, Resources for theFFuture, Inc.

Authors: W. F. Allinder, Texaco, Inc.
A. J. Laborde, Ocean Drilling and Exploration Co.

SESSION 2. PRODUCTION TECHNOLOGY
Chairman: Ira Dyer, Massachusetts Institute of Technology
Rapporteur: Frederick Wells, Resources for the Future, Inc.

Authors: E. O. Bell, Mobil Oil Corporation
C. C. Taylor, Exxon Company, USA

Thursday, December 6, 1973

9:30-12:30

SESSION 3. DRILLING TECHNOLOGY
Chairman: Willard F. Searle, Jr., Consultant
Rapporteur: Hans H. Landsberg, Resources for the Future, Inc.

Authors: W. F. Allinder, Texaco, Inc.
A. J. Laborde, Ocean Drilling and Exploration Co.

SESSION 3. PRODUCTION TECHNOLOGY
Chairman: Ira Dyer, Massachusetts Institute of Technology
Rapporteur: Frederick Wells, Resources for the Future, Inc.

Authors: E. O. Bell, Mobil Oil Corporation
C. C. Taylor, Exxon Company, USA

SESSION 1. OIL SPILLS AND CONTAINMENT
Chairman: Howard Harrenstien, University of Miami
Rapporteur: Peter Pearse, Resources for the Future, Inc.

Authors: Paul Jeffery, Warren Springs Laboratory
"Status of Oil Spill Containment and Recovery in the U.K."

W. E. Lehr, U. S. Coast Guard
"Containment and Recovery Devices for Oil Spill Cleanup Operations"

SESSION 1. TRANSPORT AND STORAGE
Chairman: George Doumani, Library of Congress
Rapporteur: Joel Darmstadter, Resources for the Future, Inc.

Authors: D. E. Broussard, Shell Development Company
"A Review of Offshore Pipeline Transport and Storage Technology"

W. E. Pieper, Brown and Root, Inc.
"Construction of Oil and Gas Pipelines and Oil Storage Facilities on the Outer Continental Shelf"

2:00-3:00

CONFERENCE SUMMARY
Harry Perry, Resources for the Future, Inc.
Chairmen and Rapporteurs

REPORT ON PANEL SESSIONS ON DRILLING TECHNOLOGY

by

Hans H. Landsberg
Resources for the Future, Inc.

Most of the issues discussed in the three sessions held by the Panel on Drilling Technology can, with some tolerance for untidiness, be summarized under the following headings:

(1) Adequacy of monitoring and recording devices and procedures (instrumentation)

(2) Personnel training, especially status and evaluation of schools

(3) Role and scope of government R&D

(4) Accident evaluation

(5) Coordination of industry regulation and range of participants

(6) Comparison of major parameters: Gulf of Mexico, North Sea, East Coast and Gulf of Alaska

(7) Miscellaneous technological aspects

(8) Consensus, dissent and attitudes

Such a grouping leaves for separate consideration only an attempt to characterize something that might be called an "industry view" as opposed to views held by academic participants and environmentalists, each based largely on wholly rational differences in the perception of risk/benefit relationships, time factors, etc. These observations are offered at the end of this round-up as a perhaps useful by-product of the panel discussion, though not as a "consensus" outcome.

The panel discussions used as their springboard the University of Oklahoma (hereafter OU) study, Energy Under the Oceans,* and, to a lesser

* Energy Under the Oceans, op.cit.

extent because of late availability, North Sea Oil and Gas,* as well as the National Academy of Engineering report, Outer Continental Shelf Resource Development Safety.** The first and third reports were specifically analyzed in papers prepared by Messrs. Laborde and Allinder. The latter also offered to the panel meeting a review of the second report. These three papers are not summarized here, but are on file in the CEQ library. Reference is made to them as needed. This report was submitted for comment to all panelists. Exceptions to the wording that indicated a significant difference of judgment or reiteration of a position not adequately reflected in the report are set out in footnotes referred to in the text.

1. Adequacy of Monitoring and Recording Devices and Procedures

A major safety hazard in drilling, not peculiar to offshore operations, is that the bit will penetrate an oil- or gas-bearing formation--an event that constitutes a potential blowout hazard. When this occurs offshore, the spilling oil can create the various types of damage described and discussed by other panels and papers.

The industry has over time evolved specific monitoring and recording devices designed to furnish sufficient advance warning of the kinds of influx from the reservoir that represent a potential blowout situation. To date, offshore drillers have a good record of maintaining control. Nonetheless, there is controversy over the adequacy of such devices within the

* North Sea Oil and Gas, op.cit.

** Outer Continental Shelf Resource Development and Safety, op.cit.

the general context of agreement by panelists that continuous efforts should be made to improve on this record.

(a) Mud Monitoring[1/]

The principal warning of changing pressure in the well casing is a change in the return flow of the drilling mud. Prevailing practice measures changes that exceed a gain in the tank of more than five barrels above normal level. Based upon their research, the OU participants question the adequacy of these devices and recommend mud monitors capable of measuring volume changes as small as one barrel be required. Industry spokesmen feel that prevailing monitors are adequate and that any greater precision would actually be counterproductive, primarily by dulling the operator's alertness. Moreover, external factors other than changes due to mud influx would produce record changes in monitoring instruments and could thus possibly mislead the operator. The position of industry spokesmen on the panel was that an accuracy of one barrel would provoke many "false alarms." They maintain that it is not the precision of the measurement (five barrels vs. one barrel--or any other number smaller than five) that is important; rather it is the reduction of the time lag between an indication of an influx and responsive action based on it. While the panelists agreed that what was important was reducing the time lag between knowledge of influx and responsive action based on it, industry spokesmen contended that the proposed change would make no contribution.

(b) Downhole Instrumentation

Panelists agreed that what was needed was provision of pressure information from within the geologic structure just ahead of the drilling bit.

Discussion of the usefulness of downhole instrumentation to accomplish this was somewhat inconclusive. Industry spokesmen were of the opinion that it would not be superior, in terms of lengthening the time between indication of trouble and response, to current instrumentation. They agreed, however, that this may be an area worthy of further exploration.

In this connection, it was noted that there do not at present exist any API standards in the matter. The rapporteur proposed that perhaps establishing these would be a worthwhile focusing point for the entire discussion centering on adequacy of instrumentation.

(c) Increased Automation

Finally, views differ strongly on the advantages of increased automation, i.e., predetermined response to indications of trouble. This has substantial appeal to some of the non-industry participants as carrying some safeguard against human error.[2/] Industry spokesmen point out, however, that what is needed is intelligent reaction to the specific incident. Often, they argue, you may not want to close the blowout preventors, for example, but take other evasive or remedial action; a preset automatic response would deprive the operator of needed freedom of action. The pit level indicator (i.e., the drilling mud parameters) is basically a trouble indicator, signalling that something is wrong. What precisely is wrong and what action is required to deal with the situation is best decided by the operator, according to drilling experts. It would seem that in this area, too, the setting of standards by API (or others) could be a useful path toward closer agreement on the limits of automation, in the sense of finding the best tradeoff point between added safety and assurance of reasonable continuity of drilling operations.

2. Personnel Training, Especially Status and Evaluation of Schools

The OU analysis lays great stress on what it calls the "man-machine interface" and cites examples of the usefulness of a systems approach to safety objectives. Unless equipment is designed to correlate with human behavior characteristics, human error will be blamed for mishaps, whereas in fact, error is partly triggered by failure to consider elements of behavior and design equipment accordingly.

The controversy in this area is palpable. Industry argues that it would be foolish if it did not provide and insist on the best possible training for drilling operators, as the potential losses of rigs, wells, and,of course, skilled manpower, would in the first place hurt the company. Thus, spokesmen say quite frankly it is perfectly reasonable to leave the formation and judgment of skills to the companies. The argument is bolstered by such observations that "schooling isn't everything," that some of the best operators have learned their job "by doing it," that excessive reliance on training might dull the sharp edge of experience, etc.

It is obvious that the industry is quite sensitive on this score, while to the outsider it would seem a minor matter whether or not the government takes a hand in setting standards for schools, operators, or both. What may be involved is both the operators' pride in their record and the industry's reluctance to let the government stick its snout under yet one other tent.

Several aspects are at issue. To begin with, non-industry participants argue for some government role in determining the curriculum and performance of schools (these would be schools to instruct mainly in the prevention of blowouts but extend also to other hazards). The NAE report, for instance, recommends specification of criteria for judging such schools as do now exist.

The USGS has put together a set of recommendations that are now under review by the API, but, of course, the API has no enforcement facilities. Moreover, the OU report criticizes the API for having only industry operators, albeit training-oriented ones, on its panel and no behavioral scientist specializing in learning theory. Indeed, the OU representatives argued that a trade association such as API is not an appropriate organization upon which to rely for assistance in setting standards and establishing requirements. An organization which is much more broadly representative should be used. This probably would require establishing an ad hoc committee for that specific purpose. At a minimum, advice should be sought from a variety of parties at interest rather than solely from the industry's trade association and interest group.

Another question raised is the capacity of existing schools. While some operators report that all their own and contractor's personnel must have gone to such a school, others do not. Were training to be made mandatory, present school capacity would likely not be adequate. What should be done to forestall shortages, and under what auspices should desired expansion occur? Consistent with their general attitude of self-reliance industry panelists argued in favor of self-regulation, perhaps through such channels as the Drillers Association. This contrasts with the doubt expressed by non-industry panelists that in the face of past mishaps this would not be enough to restore and strengthen public confidence in the adequacy of training. Only a combination of (a) inspection and certification of schools by a governmental agency, (b) requirement that all personnel employed on offshore rigs successfully pass approved training courses, and (c) a thorough evaluation of the effectiveness of such training, conducted by, among others, members of disciplines familiar with behavioral characteristics and learning theory, and paying special attention to the degree of realism of training, would contribute to inspiring confidence. However, there was some opinion expressed that one should not prejudge the issue whether schools were in fact the most efficacious way of dealing with the human factor in the reduction of hazardous events.

Since it was reported that the Occupational Safety and Health Administration (OSHA) is now moving in the direction of exercising greater government superivision of training facilities and criteria for operators, and since USGS also has become involved and is working with a broad-based review group in the National Academy of Sciences in order to tap talent beyond the boundaries of the industry, perhaps the time is propitious for dealing in a non-fragmented manner with the issues raised. This would begin by recognizing the initiatives taken and practices adopted so far by the industry so as to avoid the impression that the public has just invented a new path to safety. At the same time, industry would be wise to recognize that the arguments it marshalls against increased stress on schooling--such as that it engenders overconfidence and complacency, renders dismissals of incompetents more difficult, and that in general "industry knows best" because its own interests compel it to play it safe--will not convince a skeptical public opinion. These are arguments, non-industry panelists insisted, that could apply with equal force to many segments of economic activity in a modern society, but have been overriden for reasons of promoting public safety, of both people and places.

In approaching solutions, the Environmental Protection Agency (EPA) participant proposed it is important to ask (a) what areas of operation and what types of jobs should come within standardization of curricula and operator certification and (b) how quickly steps should be taken in order to bear fruit for drilling activities in new locations, specifically on the East Coast and in the Gulf of Alaska.

3. Role and Scope of Government R&D

One of the observations advanced by OU was that the industry had made remarkably little use of government R&D funding possibilities and that present public misgivings about extending drilling activities to the East Coast and the Gulf of Alaska might have been minimal or absent if such R&D assistance had been obtained.

Rather than reproduce a protracted and partly quite general discussion on the drawbacks or advantages of government-funded R&D (e.g., government is slow; government does not possess requisite competence; government is more impartial; government R&D can overcome antitrust bars to cooperative industry R&D; industry knows all it needs to know to commence drilling on East Coast and Gulf of Alaska; etc.), it is useful here to report on the consensus reached:

(a) A measure of government R&D is needed to provide the agencies with sufficient in-house knowledge to write and implement regulations;

(b) Government R&D will stimulate innovation where industry incentive is lacking;

(c) Incentive will be lacking where the fruits of R&D cannot be appropriated for private gain or where scale of expenditures seems to be out of proportion to gain expected to accrue to company;

(d) Areas in which government R&D appears especially appropriate are:

(i) Effect of seismic events on drilling risks (probably more important for production than drilling phase);

(ii) Extension of wave theory;

(iii) Effects of dumping of cuttings, drilling mud, etc. (no technology barrier, but important cost considerations);

(iv) Question of limits to scaling-up of technology now prevalent in traditional production areas to conditions appropriate on East Coast and Gulf of Alaska;

(v) R&D on evnironmental issues generally.

A question applicable across the board on these matters is how to anticipate areas where design problems will arise for drilling in the Gulf of Alaska and along the East Coast. What problems will be encountered by all operators with regard to ice-loading or seismic loading, for example? Will tsunamis present special problems, and what will they be?

One of the industry participants informed the panel that his company had accumulated several volumes of information on environmental parameters in the Gulf of Alaska and that the raw data were accessible for the asking. The point made was, of course, that industry had not waited for government R&D to acquire what knowledge it could.

Nonetheless, considerable discussion developed around the criteria for designing for seismic risks. Specifically, CEQ's consultant on earthquakes put in doubt an industry practice that uses building codes in the Los Angeles area as a guideline. The seismic shear-effect in the water environment is likely to be more serious than land-based effects, though in general there was agreement that in the drilling phase the likelihood of a serious accident was extremely remote, given the need for simultaneous occurrence of the event and an influx from the formation. Moreover, there is an automatic safety device in that the well would simply be sheared off; and that, in general, mobile rigs are apt to ride out seismic events.

Thus, the evaluation of the hazard from seismic events would be affected much more from consideration of production than drilling. Put differently, a decision as to whether drilling should be commenced would be based largely on a decision whether it was advisable to produce, transport and store rather than drill.

It appears clear, from this summary of the discussion, that testing the applicability of building codes in earthquake zones is a prototype of the kind of R&D appropriate for government funding and sponsorship. It was considered important by all to identify other areas for government-funded R&D.

4. Accident Evaluation

A consensus was reached, with which the OU participants associated themselves, that matters were "moving in the right direction" with regard to monitoring and analyzing accidents and alerting operators to the experience and lessons. Specifically, USGS spokesmen judged that present technology was adequate and obviated the need for monitoring devices akin to those carried in airplanes. Again, industry spokesmen argued the human element, i.e., that accidents always occurred in the presence of observers who, with the aid of recording devices, were in a position to evaluate the sequence of events. OU analysts who in their report argue for more automation in this phase as well appeared less emphatic at the panel meeting. They agreed that "we are in a period of transition" in which USGS and the U.S. Coast Guard (USCG) between them investigate and report with greatly improved efficiency.[3/]

No such consensus emerged in the matter of "near-accidents." There was strong objection on the part of industry to characterizing so-called "kicks," i.e., small gains in mud circulation that can result from a variety of causes, including minor influx into the well, as "near-accidents." Rather, these were normal occurrences in any drilling sequence. No report should, therefore, be made. While the OU analysts did not mount a major argument at the panel sessions,[4/] the point in their printed report is made strongly. There may be some merit, therefore, in trying to determine whether it is possible to identify a threshold above which a "kick" could be considered a near-miss and thus worth evaluating.

5. Coordination of Industry Regulation and Range of Participants

Perhaps more than in other areas discussed, there was strong consensus that nothing is to be gained and much lost--especially time--by fragmentation of agency participation. Clear designation of a lead agency, generally believed to be the USGS, would be most helpful. Roles of others, both public and private, such as U.S. Coast Guard, Environmental Protection Agency, Council on Environmental Quality, American Bureau of Shipping, American Petroleum Institute, and international ones such as the Inter-governmental Maritime Consultative Organization, at least should be sorted out and their responsibilities clearly related to those of the lead agency. Avoidance of conflict was considered more important at this time than addition of new regulations.

There was also general agreement on the need for a long-term (ten-year) plan of OCS development. This would permit sufficient lead time for industry to design in accordance with specific environmental conditions, for government to call for and analyze environmental impact statements, and for the public at large to find and fulfill its role in the development of this large and rich public resource to be exploited in accordance with the desires of society.

The question of the range and manner of public participation in the writing of regulations and management of OCS activities predictably could not be resolved among the panelists. Industry argued, consistent with its stand in other matters, that expertise rested primarily, and on occasion exclusively, with it, carrying the clear message that all others were interlopers, to be at best tolerated as a nuisance. At the same time, there was a clear note in industry comments that the worst of all possible conditions was one of uncertainty and that if the industry only knew what it was that government and the public wanted, it could operate efficiently. Other panelists pointed to enlarged public participation as a new fact of life to be recognized by all concerned and to lead simply to a search for its most efficient management.

Perhaps worth mentioning in this context is a spirited defense by industry of the excellence and timeliness of U.S. regulations. Specifically, it was pointed out that the Norwegian regulations (Det Norske Veritas), singled out in the OU report as especially worthy of emulation, were largely based on rules promulgated much earlier in the ABS code.[5/]

6. Comparison of Major Parameters: Gulf of Mexico, North Sea, East Coast and Gulf of Alaska

Most of the controversies taken up by the panel relate to matters in current areas of exploration and production rather than new ones. Improvement would benefit both old and new zones.

In order to focus specifically on the advisability of extending production to the East Coast and the Gulf of Alaska, an attempt was made by the panel to compare environmental parameters of major significance in the various areas and set them against rig design criteria. A somewhat improvised presentation and debate on the subject was subsequently supplemented by data compiled, at the request of the conference sponsors, by one of the panelists.

The data suggest that, seismic conditions apart, neither the East Coast nor the Gulf of Alaska are characterized by conditions of wind, waves (frequency and height), water depth or current such as are not encountered in experienced environments (Gulf of Mexico, North Sea).[6/] Indeed, wind velocity, for example, is greater in the Gulf than anywhere else, and rigs designed to weather Gulf storms could withstand those elsewhere even better.* The two charts prepared by Professor William Hise of Louisiana State University are indicative of the relationship between design characteristics and wave and wind conditions.

A major item to be considered separately (and dealt with above) is design for seismic loading; but,as agreed by the panelists, this represents at most a minor problem for exploratory drilling.

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* Mr. Allinder (Texaco) comments that "...wind velocity is not the only environmental factor that enters into the designer's calculations" and that "... the petroleum industry has available to it the environmental data and technology required for safe rig design and will use the appropriate data for the East Coast and the Gulf of Alaska."

These remarks should not, however, be interpreted to encompass hazards from drilling to environmental resources, such as aquatic fauna. The habitats differ, and the impact on living resources from discharges by rigs may also differ. The panel did not deal with this, and the above parameters do not include environmental impact, but only safety. The panel agreed on the need for background or baseline studies that could usefully be done through government R&D.

7. Miscellaneous Technological Aspects 7/

Two comments contained in the OU report relating to the existence of a "technological lag" in U.S. drilling were taken up by the panel and put in different perspective by the industry. Others are dealt with in Mr. Laborde's paper.

(a) Subsea Systems. OU suggests that the USGS encourage the early development and use of subsea systems. While agreeing that the technique should be pursued, industry contends that (1) subsea systems are relevant mostly to production and not to drilling; (2) diver efficiency is rapidly lost at depths below 500-600 feet; (3) the adverse impact on fishing tends to be greater than in the case of rigs; and (4) bottom conditions are a crucial element, thus making it difficult to generalize. OU panelists did not agree that the adverse impacts on fishing necessarily tend to be greater; but in any event, all panelists agreed that R&D is indicated to further pursue the advantages and disadvantages of complete subsea systems.*

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* In commenting on the draft of this report, Mr. Allinder (Texaco) noted that "...it is largely the same companies and designers working in the North Sea and the Gulf of Mexico. In fact, all of the subsea drilling systems were developed in the U.S. and almost all of the R&D on subsea production systems is being conducted in the U.S. ... and conducted by industry."

(b) The OU analysts cite small use of the turbodrill in the United States as an indication of insufficient communication with other technological communities. Industry spokesmen point out that the turbodrill has been outmoded by the dynadrill, as the latter's rotational speed can be controlled by varying the pump rate.

(c) Use of concrete. As another example of lacking communication with other technologies, the UO analysts note the failure of U.S. operators to utilize concrete in rigs, whereas concrete is used in North Sea activities.

Industry panelists retort that, first of all, only one concrete rig is used in the North Sea and that, in general, what is new in the use of concrete is its use in gravity structures, a point with which OU panelists agree. Employment in such manner depends heavily on the overall environment, especially bottom conditions, and needs great care.* The discussion on this matter remained somewhat inconclusive and is covered here merely to tag the matter for further consideration. (An early January 1974 news story reported that a fourth concrete production platform for North Sea service had just been ordered, the first from a British firm.)

8. Consensus, Dissent and Attitudes

To summarize, the panel did not resolve a number of controversial issues, but helped in identifying them clearly. Nor, however, did it point to problems significant enough in the drilling phase to warrant abstention from extending activities to new areas.[8/] Excepting seismic

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* Mr. Allinder comments further that soil conditions in the Gulf of Mexico are "... not suitable for supporting the tremendous weight of a concrete structure without piling" and points to the absence of deep water near shore "... which is required to build and tow a deep draft concrete structure."

conditions, participants did not point to Alaska and East Coast environmental factors sufficiently different from those encountered in the Gulf of Mexico and the North Sea to conjure up design problems not previously solved. Indeed, some current design criteria might be conservative for the East Coast or the Gulf of Alaska.

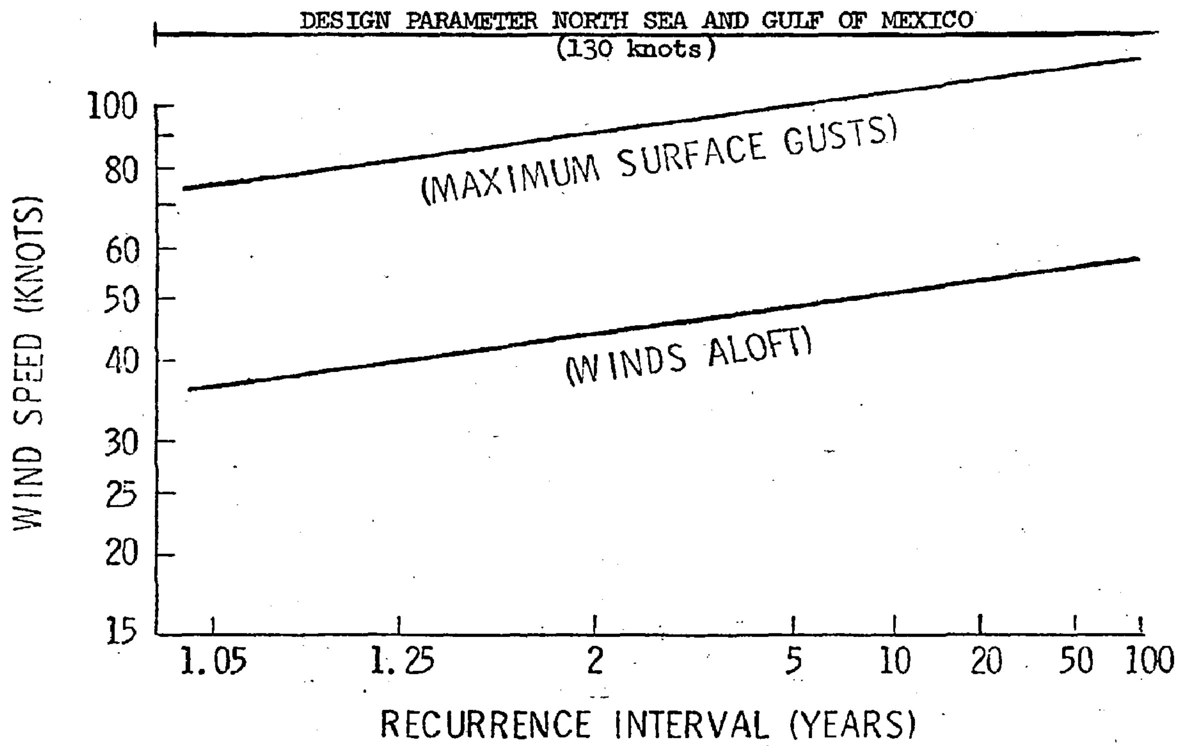
Much emphasis was put by all on a tightening up of regulatory activities, avoidance of agency overlaps or conflict, timely sorting out of environmental impact considerations and, more generally, the establishment of a regulatory framework that could be counted on to prevail for many years and thus create certainty of conditions to be met. Given the long lead time in delivery of rigs--which may be used both here and abroad and thus will fill up order books from around the world--it was felt to be most important that decisions be made rapidly and clearly so as to permit advance planning within permissible boundaries.

While generally hostile to increased government involvement, specifically in the matter of manpower development and supervision, the industry might reach an accommodation, it was suspected, if such were needed to open up additional areas for drilling and production. A brief conference is hardly adequate for forming a judgment as to the flexibility on the attitudes of either industry or public interest groups. One could not, however, help feeling that the worst way to reach accommodation was for each side to inform the other that it spoke from ignorance. Yet much dialogue is of that kind.[9/] Obviously, industry has a vast reservoir of knowledge. Equally obvious is the fact that its evaluation of risk/benefit relations, of damage to resources external to its immediate facilities, and of time horizons, differs from that reached by observers not in the industry. Finally, those arguing with the industry at times, and understandably, do not possess the specific technical expertise to "win the argument."

In these circumstances, the sequence that proceeds from identification of issues to grounds for disagreement to mechanics of resolution seems to point surely to a process of governmental involvement in which the public interest--or at least segments thereof--is represented as one of the providers of input. The panel whose deliberations are reported above is a case in point.

GULF OF ALASKA

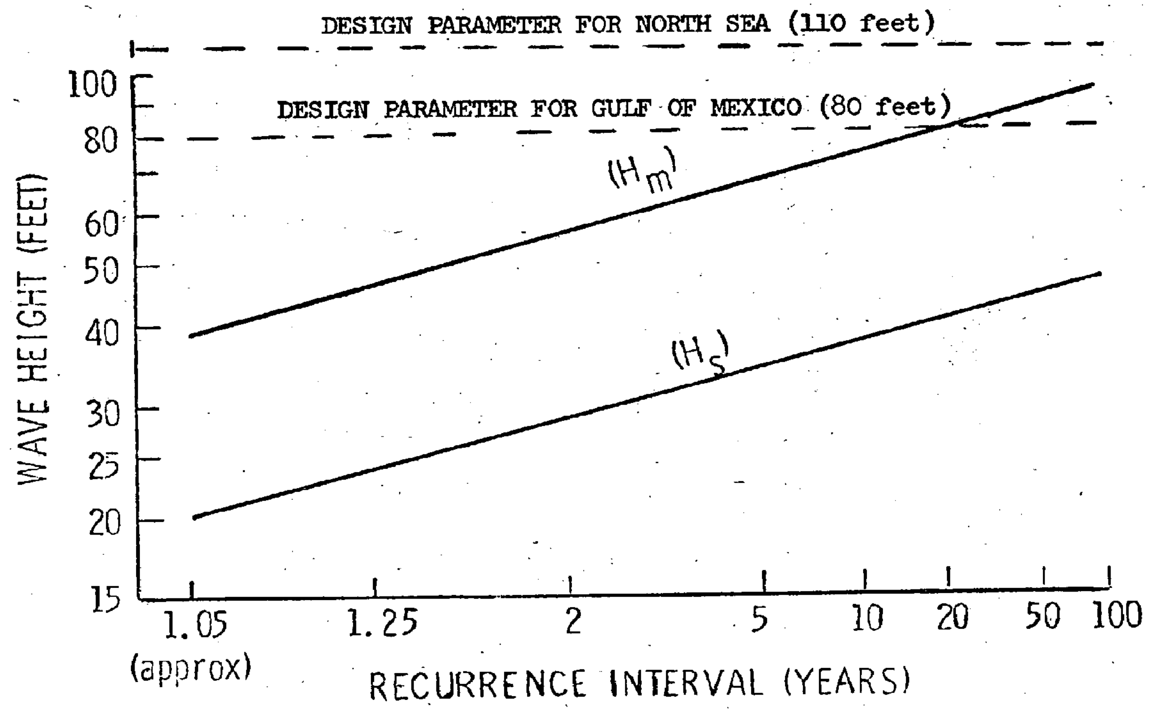
RECURRENCE INTERVAL OF WINDS



William Hise
Louisiana State University

GULF OF ALASKA

RECURRENCE INTERVAL OF SIGNIFICANT WAVE HEIGHT (H_s) AND MAXIMUM WAVE HEIGHT (H_m)



William Hise
Louisiana State University

Footnotes

1/ The OU representatives stressed that drilling activities and equipment should be viewed as an integrated man-machine system and that to discuss mud monitoring in isolation was something of a false issue. They stressed that the goal should be to improve the overall system and that one point in that system where the danger of a blowout can be detected is the mud monitoring system. Being able to measure more accurately any sudden loss of mud or increase in downhole pressure, in fact, has been identified by other industry spokesmen as a very important improvement.

2/ OU representatives again stressed that one must view drilling as a system, a man-machine system, and that in attempting to improve that system you look for weak points. Industry data indicate that the human operator is a weak link in the system. "Consequently," they comment, "we would support changes which would minimize opportunities for human errors to produce catastrophic results. This doesn't mean that we would necessarily propose that blowout preventors be closed automatically. In fact, there are times when closing the preventors would be a mistake. Indeed, we find it disconcerting, as we indicated during our sessions, that one of the papers prepared for the panel conveys the impression that the blowout preventors are a cure-all and that closing the preventors is almost routine. This is a step not taken lightly and one of the behavioral problems is that the employee who decides to close the preventors takes an action which costs considerable time and money. This can't help but influence his decision."

3/ "We agree only that possibly both USGS and USCG, but certainly USGS, have recently taken steps to improve their investigation and reporting of equipment failures and accidents. The change is too recent to say that they investigate and report with greatly improved efficiency." (OU comment)

4/ In their comments on the panel report, the OU representatives commented that "it was the terminology which was not pressed by us at the panel sessions. Regardless of what term is used, there is a lack of information about the frequency of occurrences which could cause a blowout if mishandled. These data are needed if drilling risks are to be accurately evaluated."

5/ According to comment received from the OU panelists, the point they wished to make was different. "What we identified as being suggestive," they say, "is the relationship between Det Norske Veritas and the Marine Ministry. What is lacking so often in the U.S. is this kind of relationship between a regulatory agency and an independent (classification) society. If we were to make a recommendation on this point, it would be that our regulatory agencies set performance and equipment standards recommended by independent classification societies as backed up by their own in-house expertise. Too often at present, the expertise is partisan. The ABS may not be partisan, but their standards apparently are enforced by the private insurance industry rather than by government agencies."

6/ OU representatives comment that "the data presented in this format can be misleading. These data are an inadequate description of the environments of the North Sea, Gulf of Mexico, Gulf of Alaska, and the Atlantic Coast. For example, designs for the North Sea presumably respond to more than just the conditions listed in the matrix: frequency of severe weather, warning time, percentage of time of wave heights above a set number of feet, etc. In this connection, see the technologies chapter in our North Sea report, particularly the major section on environmental conditions beginning on page 48, and our Table 3 on page 50." It is the rapporteur's "post-mortem" judgment that, while the intent of these endeavors was in the right direction, the effort devoted to it within the framework of the conference was in no way sufficient to explore the subject.

7/ Mr. Laborde comments as follows: "The material covered on this page is of possible interest but has little bearing on the basic decisions to be made. I think it merely underscores the fact that the OU group is not competent to judge and recommend on technical matters not within their personal experience or expertise."

8/ In recommending wording changes in this report the OU representatives suggested the following phrasing: "Despite some disagreement on specific improvements, panelists did agree that there are areas in which drilling safety can be improved. And it was agreed that these improvements generally do not have to be made as a prerequisite to further oil and gas development on the outer continental shelf."

9/ A case in point is the comment made by an industry spokesman, Mr. Laborde, in his review of the panel report. Suggesting that the term "public" not be used to collectively characterize the non-industry panelists, he writes: "I would be happier if you could adopt some terminology other than 'public' to characterize the views of the relatively small interests represented in the conference by the OU professors and the environmentalists--your draft seems to imply weight to the opinions of the probably less well informed latter groups equal to that of those who are in a better position to know, a commendable democratic approach, but not one likely to come to the correct conclusion in matters which depend upon fact rather than consensus or philosophy."

List of Participants
Panel on Drilling Technology
December 5-6, 1973

George F. Mechlin (Co-Chairman)	Westinghouse Research Laboratories
Willard F. Searle, Jr. (Co-Chairman)	Consultant
Hans H. Landsberg (Rapporteur)	Resources for the Future, Inc.
W. F. Allinder*	Texaco, Inc.
Daniel J. Bourgeois	U.S. Geological Survey
Michael Chartock	University of Oklahoma (Dec. 6 only)
Kenneth W. Forbes	U.S. Department of Commerce
William Hise	Louisiana State University
Li-San Hwang	Tetra Tech, Inc.
J. L. Kilpatrick	Ocean Drilling and Exploration Co.
A. J. Laborde*	Ocean Drilling and Exploration Co.
B. J. Livesay	Dresser Industries, Inc.
Gayle Oglesby	U. S. Geological Survey
Hal Scott	Florida Audubon Society
Myron F. Uman	National Academy of Sciences (Dec. 6 only)
H. D. Van Cleave	Environmental Protection Agency
Irvin L. White	University of Oklahoma

* Author of paper for panel discussion.

REPORT ON PANEL SESSIONS ON PRODUCTION TECHNOLOGY

by

Frederick J. Wells
Resources for the Future, Inc.

1. Introduction

This panel discussed whether the production technology for offshore oil and gas production is, or could be made, adequate for OCS operations in the Gulf of Alaska and the U.S. East Coast areas. In addition to the background reports by the National Academy of Engineering and the University of Oklahoma, the study of the National Aeronautics and Space Administration (NASA), "Applicability of NASA Contract Quality Management and Failure Mode Effect Analysis Procedures to the USGS Outer Continental Shelf Oil and Gas Lease Management Program," was also discussed. The two papers directly prepared for this panel were: E.O. Bell, Mobil Oil Corporation, "Environmental Protection Technology in Offshore Petroleum Completion/Production Operations," and C.C. Taylor, Exxon Company, "Status of Completion/Production Technology for the Gulf of Alaska and the Atlantic Coast Offshore Petroleum Operations."

The chairman of the three sessions of the production technology panel was Ira Dyer. In addition to the authors of the two papers presented, authors of the NASA and University of Oklahoma studies, representatives of the U.S. Geological Survey, Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Academy of Sciences, environmentalists, and other experts in the field were present. A list of panel participants is attached to the end of this report.

It should also be noted that the panel:[1]

(a) Did not address the questions of standards or criteria for environmental impact or accident avoidance. These questions, while central to appropriate technological solutions, require data and deliberations beyond the scope of available data and agreed-upon interpretations (now often detailing value-based decisions). But since a solution cannot be judged without such a specification, the panel adopted both current criteria and improvements upon current criteria as benchmarks for judgments. The panel believes this to be coordinate with its charge.

(b) Did not assess the merits of any particular overall design in OCS production technology, but rather attempted to uncover limits, if any, to technology with respect to constructed production facilities in the Alaska and East Coast offshore areas.

2. Preliminary Statements

Before the chairman developed an agreed-upon agenda, panel members were encouraged to bring up any points they thought were relevant. For example, although it was agreed that existing OCS operations in the Gulf of Mexico had improved from an environmental viewpoint--at least in part due to USGS prodding--the question arose in response to the two panel papers as to why it took the NASA report and other pressures to bring about these improvements by the industry and the OCS regulators, the USGS. That is, if the industry and USGS were doing as good a job as claimed, why was the NASA study necessary? To this it was stated that studies such as the NASA report had helped improve the performance of the USGS and the industry. The reports of studies such as the one performed by NASA have provided focal points for further industrywide and USGS actions; thus bringing together the efforts of a number of companies which had been working toward improvements in equipment such as subsurface safety valves, and in operations (as indicated in more detail in the two panel papers). Similarly, the industry was already engaged in building up records on hardware failures although these records were not public, and not much data had been taken prior to the NASA report. On the one hand, there was concern expressed over the benefits of additional government regulation of OCS activities and, on the other, it was argued that past spectacular fires and spills (e.g., the Santa Barbara spill), although few in number, have changed the public's attitude toward OCS operations and that industry, despite progress in this area, should recognize and accommodate itself even more to these concerns.[2/] In particular, the wide variations in performance among and within companies was cited as a rationale for government regulations to assure at least floor level performance.

The adequacy of the technology presently employed in U.S. operations was questioned as well. That foreign technology is often better in protecting the environment was advanced as an argument in favor of requiring higher standards. Similarly, it was claimed that better subsurface safety valves have been available for several years but are just now being required in new OCS platforms. A counterclaim was made that these safety valves were not really available for such applications and that there was a lack of demonstrative need for a more reliable valve. It was argued then that a better valve could have been developed earlier if there had been interest.[3/]

A number of other short statements were made (e.g., concerning low level seeps and spills, heavy metals around the platforms, antitrust limitations on industry cooperation, incentive programs, acceptable environmental damage levels, design criteria levels) before an agenda was set up, but most of these comments can best be included within the discussion to follow.[4]

B. Agenda

The following agenda was established as a basis for discussion:

(a) Do we have adequate quantitative descriptions of environment loads and conditions (e.g., sediment fluidization, waves, ice, wind, currents, earthquakes) as they affect operation and integrity of OCS production facilities in the Gulf of Alaska and off the East Coast?

(b) In each major subarea of production technology, and for the same accident rates and environmental impacts now achieved in the Gulf of Mexico and elsewhere, are there technological solutions that are appropriate for Alaska and for the East Coast?

(c) In each, is there technological room to reduce the accident rate or environmental impact? That is, which subareas, if any, are now saturated technologically, or soon to be?

(d) What are the nontechnical factors that may be barriers to the adoption of adequate technology?

With reference to points (b) and (c) in this agenda, the question of what level of environmental production should be achieved was set aside. It was agreed that this is a very important problem but one which could have occupied the panel for a long time. The way out of this dilemma was to first set the existing levels of performance as the standard for the new provinces [point (b)] and then [point (c)] ask if we could do "better"--"better" being undefined.

4. Quantitative Descriptions of Environmental Conditions

As far as platform design criteria were concerned [point (a)], the use of rigid or detailed specifications was thought to be inappropriate; indeed, an American Petroleum Institute (API) specification for design of offshore platforms does exist and is used by platform constructors. Experience from existing production platforms and previous losses has increased expertise in understanding wind and wave forces and bottom conditions. There is some uncertainty imposed by the lack of data on earthquakes in the Gulf of Alaska. However, although it was not clear to everyone that the following conclusion held true, it was suggested that by extrapolating from California data it would appear possible to build an earthquake-safe platform;* however, no probability statements (such as "this platform will survive the worst earthquake expected in a 100-year period") could then be made. Data on tsunamis in the Gulf of Alaska are also scanty but, in general, tsunamis only pose problems for platforms or other structures on or near the shore. In addition to uncertainties over the appropriate design criteria for new OCS operations, there could also be some problem in deciding whether a particular design would meet any given set of criteria. Again, the USGS was urged to give proper attention to the adequacy of all platform designs. The fact was brought out that the USGS

* See comment by CEQ consultant in the Drilling Panel report on the applicability of Los Angeles area building codes for use in the Gulf of Alaska (pp. 9-10).

does review the design of platforms prior to installation in any given location. The USGS was urged to continue special emphasis on such reviews, including the use of the system analysis procedures being instituted. A caution was also expressed that the public would not be well served by a program requiring platform over-design. A generally supported conclusion of this discussion was that while some environmental load conditions are not clearly known and additional data would be useful, platforms can be built in the new areas that can evidently meet the reasonable worst case conditions, even after allowance for some disagreement over what "reasonable worst case conditions" might be.

5. <u>Environmental Quality Standards</u>

Although, by means of framing points (b) and (c) appropriately, a lengthy discussion on suitable environmental standards was avoided, some brief comments were made on the subject. It was pointed out that the status of biological knowledge and understanding was too low to quantify existing background on baseline conditions, and, therefore, to judge impact; also, that little was really known about the biological effects of oil spills and seeps and other pollutants such as heavy metals associated with OCS production.[5/] On the other hand, it was argued by industry that the impacts in existing areas had been almost zero, and, indeed, fish catch had increased in the area. Environmentalists strongly disputed the association between rising fish catch and OCS operations in the Gulf of Mexico and argued that these industry claims are invalid because of the lack of data.[6/] In any event, since fish species and the ecology of the new areas may differ, the record for the Gulf of Mexico operations would not, it was suggested, resolve the problem.

The upshot of all this uncertainty is that many standards are simply figures "pulled out of the air," based mainly on technological and cost factors, and that these standards keep shifting as technology is improved with the result that it is difficult for OCS operators to keep up (but, of course, this improvement of technology was cited as a reason for maintaining flexible standards). Clearly, more information would be very helpful in this area.

6. General Observations on Technology

Under points (b) and (c)--and to some extent, point (d)--a number of general and specific areas were discussed. One observation was made that the costs would be greater for the production platforms in the new areas, especially off Alaska and that setting up the platform and laying pipe would, because of storms, be more of a problem than in the Gulf of Mexico. However, after a platform was established, operations, risks, etc. would be more or less like those in the Gulf of Mexico. It was also pointed out that within the industry, failure reporting and analysis systems, as recommended by NASA, are being set up and are proving valuable in preventing breakdowns of safety and antipollution equipment.

7. Safety Valves

Specific interest was expressed in both subsurface-controlled and surface-controlled subsurface safety valves. As well productivity and pressures decline, subsurface-controlled valves are not always completely satisfactory. The surface-controlled subsurface safety valves now being installed on new platforms upon orders of the USGS are evidently proving more reliable, with more than a thousand valves now in service. It was pointed out that the API recently (November 1973) issued specifications covering design, manufacture, testing, installation and operation of subsurface safety valves (surface- and subsurface-controlled). Use of these specifications by manufacturers and operators will be required by the USGS. During the discussion the comment was made that issuance of these specifications is an extremely significant step in ensuring reliable valves for all new offshore installations. Another area also undergoing change is the measurement of pressures at the drilling bit. This is seen as an added device to avoid blowouts and appropriate equipment for this has recently been successfully tested. In terms of additional blowout prevention and control devices, it was suggested that there is a need for continued efforts to improve downhole safety devices. One panelist urged that as a last resort control device, positive-acting master subwaterline valves--perhaps manually operated by scuba divers--be considered. Industry panelists argued that such valves would be another potential source for oil leaks, that maintenance would be difficult and costly, and that such installations could not be economically justified on past history.

8. Water Treatment

The separation of oil and water was discussed at length. The existing OCS average standard set by USGS is 50 parts per million (ppm) of oil in the discharge water. This standard was criticized as being completely arbitrary, having been set more with an eye towards OCS equipment capability rather than towards a desirable environmental standard. Furthermore, it now appears that EPA will become involved in this matter as well as other environmental aspects of OCS platforms such as heavy metals in the water.[7/] The existing 50 ppm concentration standard for the discharge water is an average requirement, and the upper limit is 100 ppm.

Concentrations consistently below 50 ppm have not yet been achieved in the OCS, although it was claimed that the lowest levels achieved in OCS operations seem to occur where there is an incentive to clean the water for reinjection to stimulate oil production.[8/] Of course, one solution would be to reinject the water without removing any oil. A higher level of separation might also be achieved on the platform by improved equipment such as centrifugal separators; however, tests of these devices for this purpose have evidently not been encouraging. Some operators now pipe both oil and water to shore for separation there. The lower concentrations of oil in water attainable on land (i.e., 10 ppm) result from additional space available for more equipment and fluid residence time to effect better oil-water separation. These techniques could also be applied to the Gulf of Alaska and the Atlantic areas where, with respect to this subject, conditions could be better or worse than in the Gulf of Mexico and elsewhere. It was concluded "that the present technology for water treatment is transferable to the new areas and the existing standards could probably be met. In addition, there are other techniques for improved treatment that may be appropriate."

9. <u>Workover Operations and Platform Congestion</u>

Many of the failures and spills result from well servicing and workover operations. It turns out that this is primarily a human factors problem because the multiple operation and separate contractors involved can lead to higher levels of noise and confusion. It was asserted, however, that servicing and workover operations can be performed safely if such precautions as having a supervisor for each work team and having an emergency shutdown system control located in several areas are taken.

This last topic immediately led to a discussion of the possible fire and overcrowding hazards from multiple well platforms, especially since multiple wells for each platform may be expected for the relatively expensive platforms to be built in the new areas. A question was also raised about the hazards due to the fact that these new platforms were likely to have more enclosed operation areas. It was pointed out there was no inherent reason for these factors to significantly increase the overall environmental hazard level.[9/]

10. Chronic Leaks and Spills

Control of low level and chronic spills was also touched upon briefly. It was claimed an analysis indicated that many minor spills evidently result from valve failures in the production system, but the use of sumps and drip pans tends to reduce these. At present, much effort is being dedicated to establishing specifications for production systems with increased redundancy to ensure higher reliability and thereby minimize minor spills. It was also stated that the failure reporting systems installed by many companies had helped obtain useful information on valve part and other equipment malfunctions. Similarly, R&D is being carried out now on sand erosion and erosion sensors. However, sand erosion may not be much of a problem in most of the new provinces. Nevertheless, some participants felt that the area of chronic, low level leaks and spills is one that requires more attention, especially as to the amounts of petroleum that can be lost before detection and the sensitivity of the sensors used.[10/]

At present, while the newest platforms are reported by the industry to be relatively "clean" as far as leaks are concerned and have extensive sensor systems in the production equipment, leaks are normally detected visually by the platform personnel. Some platforms have computer controlled systems and in these any malfunction is immediately detected. Control and sensor systems are under active improvement and the criteria for these systems, which must vary according to the complexity of the particular situation, are evolving. USGS is active in this area and feels that sensor and control systems should, and could, be improved.

11. Structural Aspects of Platform Integrity

The structural aspects of platforms also came under consideration. Corrosion protection methods under the guidance of corrosion engineers are evidently standard practice already and should pose no special structural problems off Alaska or the Atlantic coast. The metal fatigue problem, which is more severe for aircraft than for OCS platforms, is also under control. The conditions already experienced with platforms in Cook Inlet (Alaska) and off Australia give further assurance about structural integrity for conditions the equal or worse of those in the new areas. Possible problems with joints on platforms in deep water were raised, but joints are X-rayed and, according to the industry representatives, are not expected to be a special constraint off Alaska and the Atlantic Coast. However, research on joints is being carried out. Finally, the "muddy" sea floor conditions (sediment fluidization which has resulted in the loss of a few platforms in the Mississippi Delta region) are not present in the new areas.

12. Concrete Platforms

Borrowing from the North Sea experiences, the use of concrete platforms was examined, particularly for the Atlantic Coast areas. Some small concrete platforms have been employed in the Gulf of Mexico for about twenty-five years but only recently have larger ones been built for use in the North Sea, so there has not been much relevant experience accumulated yet. On the other hand, new technological developments are apparently not required for concrete platforms, although this opinion was not universal. The sea bottom in the Atlantic is probably on average no worse than that in the North Sea so bottom conditions would not be a constraint. Perhaps the most important constraint would be the lack of deep water ports in which to build the concrete platforms. The earthquake hazard in the Gulf of Alaska might possibly pose some special problems for concrete platforms, but there is not great interest in them yet for that area.

13. Subsea Wells

Because of the economics rather than the technology, extensive initial use of subsea completions (subsea wells in which the well is placed on the sea bottom) and other hybrid systems falling between subsea wells and ordinary platforms is not anticipated for Alaska and the Atlantic areas. Underwater wells have been successfully used at least ten years in the Santa Barbara channel. Other concepts are also under test. Fixed platforms can be established in water depths up to 600 or perhaps 1,000 feet. They are preferred by some since control of the well is much simpler. Leaks and other problems are harder to detect and control in subsea completions. Subsea wells require servicing by ships and this increases the hazards of collisions and accidents. While earthquakes and other adverse conditions tend to favor subsea wells, such conditions primarily make fixed platforms more expensive but undersea wells do not, it is claimed, offer any inherent advantage for these problems. To some, the major attraction of subsea wells is that a higher level of reliability must be designed into them because of their automatic operation. At some time in the future subsea wells might be used in conjunction with fixed platforms that are erected in the new areas. The preference for one type or another of well seems to hinge more on the relative costs rather than any inherent technological advantages in environmental protection among the alternatives, although, obviously, subsea completions would have fewer esthetic impacts.

14. Nontechnical Barriers

The fourth item on the agenda--the nontechnical barriers to the adoption of adequate technology--seemed to elicit more concern among several of the panelists. One area of discussion was the adequacy of USGS regulation of the OCS. A panelist cited a Government Accounting Office report critical of the Geological Survey OCS regulation, "Report to the Conservation and Natural Resources Subcommittee on Government Operations, House of Representatives: Improved Inspection and Regulation Could Reduce the Possibility of Oil Spills on the Outer Continental Shelf" (Report B-146333, June 29, 1973). The report points out several shortcomings of USGS regulation of OCS operations. The NASA report also made several suggestions for improved USGS performance of its duties. Throughout the sessions there were questions on the adequacy of the procedures employed by USGS.

Several people argued that more public involvement in the regulation of OCS operations was necessary to avoid the appearance of "friendly" regulation by USGS. However, it was countered that USGS and the industry had reacted constructively to these various recommendations and are actively improving their performance. Indeed, the industry representatives questioned whether the effectiveness of additional regulation is worth the cost since, from their point of view, the industry is already achieving a highly commendable record.

Although the technology may be quite adequate to achieve even higher levels of environmental safeguards in the new provinces, the human element area was identified as another important consideration or barrier in obtaining these higher levels. A number of specific problems such as identifying valves, installing valve shutoff indicators, reducing false alarm levels on sensors, reducing noise and confusion on platforms, providing adequate supervision, and overcoming worker resistance to new methods were cited. It was stated that the industry still responds more to defective equipment than to human factor needs.

Training, especially training with blowout simulators was also indicated as an area for improvement although the industry is making substantial progress in this area. Nevertheless, the training which personnel receive inthe aircraft industry (e.g., a Boeing 747 simulator trainer) was claimed to contrast sharply with the blowout control training in the oil industry. This question of government licensing of workers and supervisors of training was argued but not resolved.

15. Panelists' Concluding Comments

Near the end of the last session the panelists were encouraged to summarize their positions and bring up any additional points they wished to. The industry representatives argued that the record of OCS operations is one of solid accomplishments and that they have already made significant improvements. On the basis of their past accomplishments they offered strong assurances that they do have the capability to operate in the Gulf of Alaska and the Atlantic coastal areas. These are somewhat more remote and difficult areas but they pointed out that five years ago Canada, with less capability then, had successfully moved into these areas. While admitting that the technology could be improved, the company panelists stated the OCS operations are becoming over-regulated and over-designed so that the costs of such "improvements" exceed the benefits and useful ideas are being stifled. They asked how many USGS inspectors were needed and claimed that additional numbers would likely be a waste of resources.

Environmentalists and some government agency representatives generally agreed that the present technology could probably meet the existing standards in the Atlantic and the Gulf of Alaska but questioned whether those standards were sufficient. Although they realized that the question of appropriate environmental safeguards was not addressed in this panel, they argued that it is a critical point which would depend upon obtaining greater knowledge of the living resources in OCS areas. These panelists agreed that the costs and benefits of regulation and design safeguards should be investigated but this involved looking more carefully at the benefits, especially those external to the industry, than has been done. They also stated that there is a great need to better quantify the limits of our technology rather than to simply assume it is adequate. The question as posed is, how can the public be assured that existing technologies are sufficient if we do not know their limits? With reference to the GAO report, they also stressed the need for better control of application and management of the technology, for better planning and for broader public involvement in these processes. To avoid stifling of initiative, they recommended institutional changes which would introduce new ideas and expand the perspective of the decision making in OCS operations (e.g., the improvements rendered by the NASA study group from aerospace industry engineering concepts.)* In particular, they desired more active participation by, and inclusion of, private citizens, conservationists, etc. in the government-industry decision-making process. Specific additional areas they singled out for more attention were the chronic leak and spill problems, improved personnel training and possible worker certification, increased attention to human factors, and analysis of onshore implications of the offshore industry.

The USGS representative stated that the main topics of importance were covered by the meeting. Their primary technical problems are the water-oil separation levels and difficulties resulting from workover operations. They are adding staff to respond to various suggestions and are improving their capabilities to regulate and inspect OCS oil and gas operations.

The NASA representative confirmed that industry and the USGS have taken positive steps to implement NASA recommendations. He stated that work must continue, however, to ensure that all companies participate in putting the new procedure into effect and to ensure that these procedures become "a way of life" for future OCS operations.

Other panel members stressed a number of points in their concluding remarks as well: The need for regulatory control does exist, if for no other reason than the fact that while best practice in the industry is very good it is not always used, so minimum levels of compliance should be enforced; that the technology is adequate now should not suffice for all time, and that

* A company representative responded by pointing out that an outside advisory group has been set up to look into OCS operations.

perhaps more R&D should be conducted; while the industry and USGS have taken steps to improve operations, there is still room for further improvement so the government and public must maintain their pressure on the industry, but without imposing too many additional costs on these OCS operations; that improvements in training and human factors is probably at least as important, if not more, than improvements in technology.

16. Summary

The following summary was drawn up by the chairman, with a few changes made after its circulation among the panel members for comment.

The panel addressed the following questions with respect to OCS production technology:

(a) Do we have adequate quantitative descriptions of environment loads and conditions (e.g., sediment fluidization, waves, ice, wind, currents, earthquakes) as they affect operation and integrity of OCS production facilities in the Gulf of Alaska and off the East Coast?

(b) In each major subarea of production technology, and for the same accident rates and environmental impacts now achieved, are there technological solutions that are appropriate for Alaska and for the East Coast?

(c) In each, is there technological room to reduce the accident rate or environmental impact? That is, which subareas, if any, are now saturated technologically, or soon to be?

(d) What are the nontechnical factors that may be barriers to the adoption of adequate technology?

The panel reached the following major conclusions:

(a) With respect to environmental loads, the panel found that while some environmental conditions are not clearly known, we can evidently meet the "reasonable" worst case conditions through appropriate design and operation.[11/] Hence lack of precise knowledge of environmental conditions, while otherwise desirable, is not a barrier to production activities in Alaska and/or the East Coast OCS.[12/]

(b) With respect to the transfer of technology to the new areas, the panel considered as the most relevant to its responsibilities the following:

-- structures
  . configuration
  . materials and fabrication
  . foundations
-- water treatment systems
-- safety valve systems
-- general sensor systems

In each case the panel concluded that technological solutions (alternatives) exist for transfer to the new areas. These solutions are generally based on present practice and do not include significant needs for developing new technology.

(c) With respect to meeting more stringent standards or criteria, the panel concluded that there is room for technological improvement, and that further development towards this end may either be desired or required.[13]

(d) With respect to nontechnical factors, the panel concluded that technology management could be profitably further developed. Thus

-- training

-- quality control engineering

-- human factors and man/machine engineering

-- regulatory engineering

could be improved.

Footnotes

1/ To this list the Oklahoma University panelists feel the following item should be added:

> (c) Did not consider the effects of production activities upon the regions' social structure and economy, nor did it consider alternatives to presently used technologies which might reduce those impacts. This was because the panel was instructed to restrict its discussion only to the technologies.

2/ C.C. Taylor of Exxon, in a written response, states that industry "is recognizing and accommodating itself to these concerns."

3/ This paragraph has drawn criticism in written responses by panel members. The two industry representatives make several points. They dispute the claim that better subsurface safety valves have been available for several years and are just now being required in new OCS platforms. They point out that surface-operated subsurface valves of various types have been in service for many years in foreign operations (and much of this foreign technology is the result of U.S. development); however, operations in the Gulf of Mexico experience much higher operating pressures, much lower flow rates and sometimes excessive sand production and precluded utilization of these valves without considerable design changes and metallurgical research, including development work required to establish their reliability in small tubing and in sand producing wells common to the Gulf of Mexico. The fact they were not used was not due to a lack of interest but due to the lack of demonstrative need for a more reliable valve.

The Oklahoma University panelists suggest that there is an error in the argument that foreign technology is inherently better than domestic technology. Instead, the situation is that "Some of the European countries have developed much better oil spill contingency response structures than those used in the U.S. However, the technology can best be distinguished by age rather than country; newer equipment is better and since the North Sea is brand new, its technology is, too."

4/ E.O. Bell of Mobil Oil suggests deletion of this entire paragraph and goes on to point out that: "The inclusion of the item 'heavy metals around the platforms' implies some authenticity to the claim, whereas to date there has been no scientific evidence presented to substantiate such a statement."

5/ See footnote 4/concerning heavy metals.

6/ Barbara Heller, of the Environmental Policy Center, has filled out this argument as follows: "Industry claims [of negligible impact on biological life due to existing Gulf of Mexico operations] were based on the fact that menhaden have only in recent years been harvested in significant commercial volume, and thus contribute to the industry's statistical data on [increasing] fish catch; that although equipment has been modernized and effort has increased, shrimp catch per man has decreased; and that industry claims are invalid because there is no base case biological data available from the period before oil was developed in the Gulf."

7/ See footnote 4/ concerning heavy metals.

8/ In written response, E.O. Bell states this sentence "implies that if there was an incentive to reduce the oil discharge levels to ten parts per million [the standard for land-based operations] that technology is available to achieve this. I believe the industry panelists presented sufficient evidence to refute this implication. The industry cleans the water to the lowest level of oil possible whether it is to be returned to the Gulf for disposal or whether it going to be reinjected to stimulate oil production."

9/ Barbara Heller comments that this point was not made clear. "In fact, multiple wells [on a single platform] could result in serious environmental damage and danger to workers since there is no technology for determining which well on a multi-well platform is on fire."

10/ C.C. Taylor states that the amount of petroleum that can be lost before detection "is of small magnitude."

11/ Barbara Heller points out that, although we "can" evidently meet the reasonable worst case conditions, we often do not.

12/ Barbara Heller states: "I disagree--lack of knowledge of environmental conditions should be a barrier to some production activities in some parts of these new areas. Such knowledge is not merely "desirable" but necessary if we are to maintain environmental integrity while producing offshore.

13/ With respect to summary points (b) and (c), as well as the other conclusions and the entire agenda of the production sessions, the Oklahoma University panelists comment: "Our principal concern with the summary is that it does not adequately recognize the limitations under which the panel worked in looking only at production technology. We think that the major problems in development of the Gulf of Alaska and East Coast OCS will be at the many interfaces between the technologies and the rest of society rather than within the technologies per se."

In elaborating this point, they argue that merely meeting the existing levels of accident rates and environmental protection in the new areas [agenda point (b) and summary point (b)] is not likely to be adequate. For example, they point out that petroleum does not evaporate or disperse as well as in the colder waters of the new areas, especially the Gulf of Alaska, as in the Gulf of Mexico. Merely to meet Gulf of Mexico standards may not be at all sufficient, therefore. Similarly, while the sight of oil derricks offshore may have little effect on the residents on the Gulf of Mexico, the tolerance for such platforms may be much less on New York's Long Island where heavy concentrations of people are located. These realities should have played a larger part in the discussions (e.g., more elaboration of subsea wells) even if some of the objections and constraints to OCS operations in the new areas did not seem to be totally "rational" to all panelists. That is to say, although technological improvements to improve environmental standards were considered [agenda items (c) and (d) and summary items (c) and (d)], more attention should have been paid to these issues with reference to the particular problems and public demands confronted in the Gulf of Alaska and the Atlantic Coast.

List of Participants
Panel on Production Technology
December 5-6, 1973

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Frederick J. Wells (Rapporteur)	Resources for the Future, Inc.
E. O. Bell*	Mobil Oil Corporation
Thomas J. Charlton	Environmental Protection Agency
Morris K. Dyer	National Aeronautics and Space Administration
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R. Leon Leonard	University of Oklahoma
Louis McBee	U.S. Geological Survey
Price McDonald	U.S. Geological Survey
Marvin Singer	Council on Environmental Quality
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REPORT ON PANEL SESSION ON OIL SPILLS AND CONTAINMENT

by

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1. Introduction

The panel and participants in the session devoted to oil spill control over the Outer Continental Shelf (henceforth OCS) represented a wide diversity of expertise and experience. The discussants had the benefit of prior study of two up-to-date papers which reviewed the state of the art in the United States, the United Kingdom and elsewhere,* technological reports of the Technology Assessment Group at the University of Oklahoma** and of the National Academy of Engineering;*** and other published information. Additional data and illustrative material were presented during the session. (Some of this material is now on file at Resources for the Future.) In the light of this background information and the direct knowledge of the participants, the session attempted to assess the adequacy of known technology and procedures for coping with oil spills in the diversity of conditions likely to be encountered in OCS areas off the United States.

As is the case with all phases of oil and gas production, direct experience with oil spills in OCS conditions is small in comparison with the considerable experience in inshore areas. Moreover, much of the rapidly-developing technology for OCS operations has been derived from equipment and procedures developed for inshore conditions adapted and modified to

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* Cdr. W. E. Lehr, "Containment and Recovery Devices for Oil Spill Cleanup Operations"; and P. G. Jeffery, "Status of Oil Spill Containment and Recovery in the U. K."

** Energy Under the Oceans, op.cit., and North Sea Oil and Gas, op.cit.

*** Outer Continental Shelf Resource Development Safety, op.cit.

accommodate the more rigorous sea, weather and logistic conditions encountered in offshore areas. As the following summary suggests, considerable progress has been made; but because of the relatively limited experience with actual offshore operations, the obvious constraints on extensive experimentation with oil spills, and the very wide range of possible conditions with respect to kinds of spills, their magnitude, sea and weather conditions in offshore areas, some uncertainties remain about the efficacy of certain approaches to containment, cleanup and dispersion in OCS regions and their environmental implications. Further research and development on all aspects of this problem is proceeding at an impressive rate both in the United States and in northern Europe.

There is a general feeling among those who are concerned with oil spills that prevention is the real key to the spill problem (as distinct from dealing with accidents that occur). Improved controls, modification of handling systems and general good housekeeping on oil production and transport operations offer considerable scope for reducing the frequency and volume of spills. However, the panel recognized that these matters fell largely under the purview of other working groups and, having emphasized the importance of preventive measures, addressed itself to the problem of dealing with inevitable accidents.

2. Approaches to Oil Spill Control

When an oil spill occurs, the decision makers face an identifiable variety of options for dealing with it. Present technology offers choice among the following: (a) leave it, (b) burn it, (c) sink it, (d) contain and remove it, and (e) disperse it. Each of these approaches presents its peculiar problems, and no one of them is likely to be the best choice in all cases. In the following paragraphs the state of the art in each is summarized briefly with a view toward establishing the most promising approaches, our general capacity to cope with oil spills in OCS conditions, the outstanding problems and remaining issues of professional differences of opinion.

(a) Leaving Spills

In some cases it would be appropriate to leave spills in offshore waters, even though the same spills would require cleanup measures in inshore areas. Small spills, which occur in rough seas under adverse weather conditions, may pose little threat to shoreline or marine life. These might well be left to be eliminated by natural processes of turbulent dispersion and biodegradation. It is worth noting that recent studies tend to suggest that the ecological effects of oil in the marine environment are not as severe as they were often believed to be. It should be noted also that the feasibility of cleanup measures is often constrained by rough sea conditions and (other things being equal) rough waters will enhance natural dispersal processes and accelerate biodegradation of oil. Whether a spill warrants cleanup attempts must, of course, be decided in the light of its special circumstances. The remaining discussion is addressed to corrective measures that might be adopted.

(b) Burning

Oil can be burned on the surface of the sea, but complete destruction of an oil slick by this means is not usually possible. Moreover, burning produces a pall of black smoke which raises additional environmental concerns. There is some feeling that further research might demonstrate that oil can be successfully burned if it is concentrated and if burning agents are added. It is possible that the smoke problem might prove to be inconsequential in many offshore areas. Generally speaking, however, burning is not now considered to be among the most promising approaches to oil spill disposal.

(c) Sinking

Oil can be caused to sink to the bottom by the addition of special sinking agents. This process presents a number of problems, the most serious of which is that the sunk material does not remain stable at the bottom. Tests in Holland and elsewhere indicate that the sunk material is likely to move both horizontally and vertically under the influence of currents and wave action. Thus sinking is also considered to be among the less promising approaches for effectively dealing with oil spills.

(d) Physical Removal

Where the oil can be physically recovered from the sea, this approach is generally preferred on environmental grounds. Success is very much a function of sea-state. And while this will often--probably usually--be possible with available equipment, it will nevertheless be impossible more often in offshore conditions than inshore where considerable experience has already been gained with these techniques and where less severe sea conditions usually exist.

Physical recovery requires a device to contain and concentrate the oil and equipment to pick it up (it also requires, of course, a good deal of ancillary equipment to store, transport and dispose of the oil and a variety of support facilities). Hundreds of devices for containing and removing oil have been developed or proposed in the United States and elsewhere in recent years. Some of these have been shown to function effectively in conditions commonly encountered in inshore waters, and a much smaller few have been demonstrated to perform in more demanding conditions typical of OCS waters.[1/] In the United States, heavy emphasis has been placed on the development of mechanical containment and recovery techniques (as opposed to chemical dispersal--see below) although considerable research and development has taken place in Britain, France and elsewhere as well.

The most promising devices for containing and concentrating oil consist of floating mechanical barriers towed or anchored, sometimes on drifting sea anchors. The BP multiple tube barrier, the Exxon bottom tension float and skirt barrier, the Coast Guard's fence boom, and the so-called Navy Boom have all demonstrated considerable success, although each has its own shortcomings and limitations.* Major difficulties lie in designing devices sufficiently strong to withstand heavy stress yet flexible enough to conform to the surface of rough water, and at relative speeds slow enough to avoid escape of the oil under or over the barrier. Certain configurations of winds and currents create severe difficulties in maintaining the required position, shape and speed of the barrier relative to the oil slick.

The most promising recovery systems under development include the weir skimmers of Ocean Systems and Clean Seas Corporations, the Lockheed disc boom produced under Coast Guard contract, the inclined plane, the French vortex device and the BP toroidal rotating disc skimmer. These vary considerably in capacity and other characteristics. There is also a variety of sorbent systems: traditionally straw was broadcast to soak up oil for

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* For a review of these devices, see Lehr, op.cit.

subsequent recovery and disposal, but this presents serious difficulties for cleanup. More recently, systems employing recoverable and reuseable polyurethane foam have been developed for this process, and another approach involves a continuous sorbent belt mounted on a vessel to retrieve the oil. The efficiency of sorbent systems varies considerably with different types of oil, however.

In summary, the effectiveness of mechanical containment and recovery systems are very much a function of environmental conditions. Existing devices can, in general, perform adequately in seas of 5- to 6-foot significant wave height, winds of 15 to 20 knots, and currents not exceeding 1-1/2 knots. In OCS regions of the United States such conditions are not exceeded most (perhaps 80 percent) of the time, but a significant proportion of the time they are. It is possible that accidents may be more likely at such times.[2/] Moreover, certain patterns of winds and waves interfere with the efficiency of mechanical devices. In some sea conditions it is almost impossible to maintain the relative speed between floating equipment and the water at a slow enough rate. Thus, while these mechanical techniques are likely to prove effective in most OCS conditions, present technology does not ensure their success in all circumstances. Further research and development is needed, and some is continuing, in this area.

(e) Dispersants

Chemical dispersants have been used extensively in the United Kingdom, the Persian Gulf and elsewhere to eliminate oil spills. This approach has the distinct advantage that it can be used in rough water--as long as the sea is even navigable. There is no doubt that chemical emulsifiers are effective in dispersing oil. Highly successful dispersal techniques have been developed and used in rough waters of the North Sea where mechanical recovery methods can not be used.

The main apprehension about chemical dispersal concerns its ecological impact. In the United States, particularly, there has been a reluctance to adopt this method because of remaining uncertainties about the toxic effects on ocean biota of dispersants and dispersants mixed with oil. In the United Kingdom, on the other hand, the use of dispersants is a favored approach, and there is considerable evidence that the impact of dispersants, properly used, on the marine environment is less than many people have hitherto believed.* Certainly the more recently developed chemical dispersants are very significantly less toxic than earlier types (such as used in the Torrey Canyon spill). It is reported that even in areas where dispersants are used regularly to deal with recurrent spills (such as Milford Haven) there is little evidence of significant and lasting ecological damage.

3. Recovery vs. Dispersal

There is no doubt that professional opinion continues to differ about the ecologically damaging impact of chemical dispersants, and there is generally more apprehension about their effects in the United States than in the United Kingdom where they have been used extensively. The concern in the United States centers on the lack of sufficient scientific knowledge about the long-term chemical and biological processes that take place and the toxic effects not only of the chemicals used but also of the chemical mixed with oil and of dispersed oil droplets.

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* See Jeffery, op.cit.

Nevertheless, it is generally recognized that, in view of the present limitations of mechanical techniques, chemical dispersion sometimes offers the only alternative to leaving the spill uncontrolled. There is wide agreement that if spilled oil can be physically recovered and safely disposed of this is to be preferred, because it removes all strains on the ocean ecosystem. But physical recovery techniques are limited by the sea and weather conditions that prevail, and in rough conditions the equipment fails and men cannot work in small craft.[3/]

These sea and weather conditions do not constrain the use of dispersal techniques. Moreover, chemical dispersal systems are exceedingly flexible in dealing with spills of widely ranging magnitude, whereas mechanical recovery equipment has necessarily a less flexible capacity.[4/]

It is generally acknowledged, also, that the hitherto strong aversion in the United States to the use of chemical dispersants is probably unjustified. While some concern remains about their ecological impact, their use is often likely to be preferable to the alternative of leaving spilled oil on the sea where physical recovery cannot be accomplished.

This is not to suggest, of course, that chemical dispersants should be used generally. Even the strongest advocates of dispersants recognize that there will be situations of special ecological sensitivity where they should be avoided, and each case must be considered in the light of its particular circumstances and the alternatives available.

In short, there is some consensus that a more flexible stance toward the use of the less toxic chemical dispersants--carefully and judiciously applied--is desirable in the United States. Dispersants offer a promising means, indeed the only means, of dealing with oil spills that cannot be physically recovered, and as such, they have an important role to play in a comprehensive and integrated program for oil spill control.

4. Research and Development Needs

Continuing research and development will undoubtedly improve our capability in dealing with oil spills in offshore areas.5/ It is the opinion of the participants in the session that special effort should be directed to the following:

(a) The movement and trajectory of oil on the surface of the sea under various weather and ocean conditions. A greater understanding of this problem is necessary for efficient planning and deployment of control methods.6/ A related issue is the need for careful inventorying of sensitive shorelines and marine waters, so that appropriate measures can be quickly identified in the event of a spill.7/

(b) The chemical and biological processes that take place when oil is added to the marine environment, and when dispersants are added and mixed with oil. Further study of these processes is essential to an adequate understanding of the impact of these materials and hence also to an informed prescription of the best control technique.

(c) The behavior of containment and recovery devices in widely ranging sea and weather conditions. In particular, there is a need to develop devices (perhaps unmanned) capable of operating effectively in cold climates, fast currents, and heavy seas. There is an urgent need, also, for tow vessels capable of maintaining steerage and control at very low speed.

(d) Particularly important is the need to experiment and test various devices with spills in varying conditions. Experience is critical and should be obtained as quickly as possible with adequate safeguards through experimental spills.

(e) Similarly, devices are required for dealing with spills that range widely in volume. Different measures, for example, are required for dealing with small spills and leaks that are common around oil operations than are appropriate for large spills at sea.8/ In addition, there is a need for substantially improved preplanning and response capability that can cope with a wide variety of spills and leaks.9/

(f) Further development of nontoxic dispersants.10/ Dispersants have improved considerably in recent years, and further development of innocuous emulsifiers is likely to relieve much of the continuing concern about their ecological effects on the ocean environment.

Footnotes

1/ Mr. Berry (Shell Oil Company) advised that these techniques are already being used on the OCS and that several cooperative organizations stockpile and use the equipment routinely when needed.

2/ Mr. Salomon (Atomic Energy Commission) suggested that the various OCS regions have environmental conditions that vary considerably, with the most severe being in the Gulf of Alaska and the Pacific coast, followed by the Atlantic and Gulf coasts. In place of an 80 percent time for which the stated sea conditions are not exceeded, he proposes that 60 percent would be more accurate.

Mr. Berry commented that experience to date does not confirm that accidents are more likely to occur when the boundary conditions are exceeded for containment systems. Mr. Golay (Chevron Oil Company) concurs and had suggested that the sentence be deleted.

3/ Commander Lehr of the Coast Guard disagrees with the statement that in rough seas the equipment fails and men cannot work in small craft.

4/ Commander Lehr is not convinced of the flexibility of chemical dispersants as described in this sentence, nor does he agree with some of the language in the next three paragraphs where optimism is expressed over the use of chemical dispersants.

5/ Mr. Jeffery (Warren Springs Laboratory) suggests that an Item (g) be added that reflects the need for planning a logistic and response capability in advance of spills.

6/ Mr. Berry believes that this type of information is of little value in handling an actual spill but is extremely valuable in planning for optimum site locations (for superports, etc.), so that locations can be selected that will result in minimum environmental damage in the event of a spill.

7/ Mr. Berry comments that this and the thought expressed in the last sentence of recommendation (f) [p. 10] are not really R&D needs but should be included as part of any oil spill contingency plan.

8/ Mr. Berry suggests that there is little difference, other than scale, between devices applicable for handling large and small spills.

9/ See footnote 7/.

10/ Mr. Golay emphasizes that the greatest potential for cleanup is the development of nontoxic dispersants.

List of Participants
Panel on Oil Spills and Containment
December 6, 1973

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Peter H. Pearse (Rapporteur)	Resources for the Future, Inc.
William L. Berry	Shell Oil Company
John Cunningham	Environmental Protection Agency
Claude E. Golay	Chevron Oil Company
J.B. Hundley	Atlantic Richfield Company
Li-San Hwang	Tetra Tech, Inc.
Paul G. Jeffery*	Warren Springs Laboratory (United Kingdom)
W. E. Lehr*	U.S. Coast Guard
Jerome H. Milgram	Massachusetts Institute of Technology
Bruce Pasternack	Council on Environmental Quality
Stephen N. Salomon	U.S. Atomic Energy Commission
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REPORT ON PANEL SESSION ON TRANSPORT AND STORAGE

by

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In a single--and, in retrospect, perhaps too brief--session, this panel addressed itself to the adequacy of technology for offshore pipeline transport and storage and, in a more cursory treatment, to related economic and environmental questions. (Since there is now and prospectively only negligible tanker shipment of petroleum from OCS producing areas, that topic, being part of the more general hazards of ocean transport, was excluded from special consideration here.)

Broadly speaking, the authors of the two background papers* both expressed a strong conviction that most existing pipeline and transport technologies (especially the former) have demonstrated their overall integrity in such diverse geographic settings as the Gulf of Mexico, offshore California, Cook Inlet, Persian Gulf and North Sea; and that, therefore, these technologies, either "taken off the shelf" or "scaled up," are applicable or adaptable to conditions which may be encountered in such newer OCS regions as the Gulf of Alaska and the U.S. East Coast.[1/] [2/]

Confidence in the transferability of prevailing technology applies particularly to pipeline construction and operation since that, rather than storage and tankerage, has been the overwhelming mode of handling OCS oil and gas production in U.S. waters.[3/] However, experience with major offshore storage facilities has in recent years been gained in the Persian Gulf and, to a far lesser extent, the North Sea and Indonesian waters. A variety of physical and economic factors were cited as determining the relative virtues of pipelining vs. storage and shipping; e.g., size and type of field,

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* D. E. Broussard, "A Review of Offshore Pipeline Transport and Storage Technology," and W. E. Pieper, "Construction of Oil and Gas Pipelines and Oil Storage Facilities on the Outer Continental Shelf."

distance from shore, depth of water, availability of onshore market and/or transhipping facilities, capability of submarine pipelaying equipment, and sea conditions.4/ It is likely that, in the light of these criteria, the use of particular transportation alternatives will be continuously re-evaluated; conceivably, the future balance of advantage will not lie as one-sidedly with pipelining as in the past.

It may be useful to recapitulate, in the most compressed fashion, the principal conclusions reached in the two prepared papers and in oral comments by their authors at the panel discussion:

> Mr. Pieper (of Brown and Root) observed that repair and maintenance of submarine pipelines are a more formidable task than land pipelines and can be more difficult and expensive than their original undersea installation. Consequently, higher standards and more rigorous inspection procedures apply. The offshore pipeline construction industry presently has a demonstrated ability to lay 32-inch diameter pipe in 420 feet of water and a presumed ability to do so at depths of 600 feet. 5/ Engineering modifications and improvements are thought likely to permit laying large diameter pipe at 900 feet and to permit trenching at 500 feet. 6/ The North Sea is the principal testing ground for these developments. While commenting on the need for technological improvements aimed at expediting the pipelaying process and welding of joints, the author did not identify such desirable advances as necessary environmental safeguards or as a constraint on the feasibility of proceeding with deeper OCS development.

> Mr. Broussard (of Shell Development Co.) underscored what, in his view, is an exceedingly attractive safety record both in the case of onshore and offshore pipelines. 7/ Since damage from external equipment is an important cause of all pipeline failures which do occur, offshore lines are far less susceptible to this danger. Pipe corrosion is conceded to be another potential source of failure. For this reason special emphasis has been given to the design and construction of corrosion mitigation systems for offshore pipeline. The absence of corrosion problems on systems built in recent years has demonstrated the effectiveness of these techniques. The author is encouraged by the fact that "frequency of failures attributable to defective pipe, defective pipe seams and to defective welding is very low, especially for pipeline systems installed since 1960." 8/ The author generally concurs with the National Academy of Engineering's evaluation, though he feels the NAE underrates the extent of cooperative industry research activity. He is more critical of the University of Oklahoma's indictment--unjustified in his view--of pipeline systems as a major source of chronic

> offshore pollution and of the consequent Oklahoma recommendation for much more extensive detection and monitoring routines. The author characterizes this as an economically burdensome solution stemming from an erroneous interpretation of Coast Guard oil spill data. The author reported that his check with the source of the data found that very few oil spill incidents were attributable to pipeline transportation facilities. The Oklahoma report is also faulted for failing to see that the forced use of multi-phase oil-gas pipelines, which it supports as an economizing measure, actually represents a diseconomy. 9/ The author supports the Oklahoma call for more extensive research into the environmental planning for the bringing of pipelines ashore. 10/

As noted, the Oklahoma study contention that offshore pipelines were a major source of offshore pollution was not accepted; and, in the course of the surrounding discussion, it became apparent that interpretation of data on offshore spillage is seriously impaired by gross deficiencies in statistical reporting systems. The question of data reliability and reporting systems led logically to a discussion by the panel of jurisdictional responsibility over, and definitions of, offshore pipeline systems; and in this regard nearly all those present seemed to agree to the fact that we now have a barely workable and jurisdictionally highly fragmented accident reporting system. The ultimate absurdity of this situation is illustrated by the anomaly, in the case of multi-phase oil-gas pipelines, of the Federal Power Commission having responsibility for the natural gas flow and having only very limited legal mandate over the oil.

Turning to some of the technical issues, the industry experts at the session reflected an overall judgment that the variety of weather and seismic experiences in the producing provinces of the Gulf of Mexico, North Sea, offshore California, and Cook Inlet provide the industry with reassurance in being able to cope with problems which may be encountered in the Gulf of Alaska and Atlantic OCS. 11/

There was a good deal of discussion concerning trenching techniques. Clearly, there are some sticky problems--e.g., disposition of spoils when bringing lines ashore in coastal industrial and populated zones where pipeline laying may cause a dispersion of otherwise settled industrial pollutants; and insuring that pipelines remain buried and secure. The former problem is sure to arise when pipelines to, say, Long Island and Virginia are contemplated. But the panel seemed to find this a problem not so much of technology as one of jurisdiction, land-use planning, and overall management decisions. An appropriate monitoring of trenching activities is also in order. A generalized conclusion emerged from this particular aspect of the deliberations as well as from other parts of the discussion: a bridging of jurisdictional demarcation lines among various federal and sub-national agencies, having supervisory responsibility over different aspects of pipeline and terminal operations but which provides for adequate representation of all interests involved, is absolutely vital.[12/]

Industry representatives seem disinclined to perceive an increased environmental risk as pipelines are laid at greater depths; instead, they emphasize the far greater financial investment--hence inducement for enhanced safeguards--under those conditions.[13/] Pipelaying at a depth of 900 feet, as already mentioned, was judged feasible. For a time, diver capability was seen as a limiting factor in deep sea development, but today, this is no longer felt to be the case. (However, the topic of diver depth constraints and the question of remaining R&D tasks were not pursued by the panel.)

There was some discussion among the panelists of storage and tanker transport where distance and other economic (and possibly environmental) factors pointed to that as the preferred means of bringing oil ashore. The permanent, bottom-founded offshore storage structures (as in the Persian Gulf and Ekofisk field of the North Sea) are not acceptable in the Gulf of Alaska because of seismic risks. Here, there would have to be floating structures, whose design features--to safeguard against rupture and potentially serious spillage--could include compartmentalization and double hulls (i.e., essentially the same protective features appropriate to tankers).[14/] Partly because of transport economics, storage was pictured as an option more likely to be exercised in the Gulf of Alaska than the Atlantic OCS, but pipelines to shore should not be ruled out in the Gulf of Alaska.

It may be hazardous to depict the emergence of a panel consensus. The relative shortness of time for discussion, possible skewness in affiliations, reticence by some panelists, etc., argue against a statement of a clear-cut majority viewpoint. That having been said, it does seem that the discussion pointed to pipelining and storage in the Gulf of Alaska and Atlantic OCS as posing a technologically manageable set of problems, although there are clearly some bothersome issues--especially those of jurisdiction, planning and management, environmental safeguards, and monitoring.

Footnotes

1/ Mr. Hallman (Center for Law and Social Policy) makes three general observations with respect to the two background papers:

(a) He feels that neither paper addressed itself sufficiently rigorously to environmental problems. Whether, in the adaptation of existing experience to the newer OCS areas, one is apt to confront a greater or less environmental risk is just not clear.

(b) A clearer distinction should be made between the transferability of prior pipeline experience, on the one hand, and storage experience, on the other. In this connection, Mr. Hallman expresses doubt, for example, on the relevance of floating storage tank experience in the Persian Gulf, an area of little turbulence.

(c) He feels that undue reliance is being placed upon "alleged experience" in the North Sea and Cook Inlet. This provides a very limited operating record which, he believes, does not warrant a sense of complacency.

2/ The OU group comments: "We do not understand the meaning of 'demonstrated their overall integrity.' We believe that the pipeline technologies are adequate, and can be adapted to conditions elsewhere, but the lack of a systematic accident reporting procedure precludes the use of the term 'demonstrated' as this information is only available for restricted elements of the pipeline system. Accidents with major trunk pipelines have resulted in breaks that have released more oil than blowouts, and gathering lines have hundreds of leaks per year. Importantly too, old pipelines can be expected to increase their frequency of leaks. The issues should be cast in terms of establishing a reporting system to demonstrate something, and to improve safety and inspection procedures to deal with increased depth, old pipe, etc." In addition, OU questions whether problems might not be expected in new areas when dealing with specific bottom conditions--earthquake hazards and ice conditions, for example.

3/ OU comments that "the level of confidence in the tranferability is relative to the safety record." Believing this record to be "spotty," they would have preferred to have seen this paragraph cast in terms of the "level of confidence" rather than an absolute degree of confidence.

4/ Mr. Hallman would like to have seen some discussion of the economic-environmental tradeoffs of a small number of large-throughput pipeline systems vs. a large network of low-throughput systems. Mr. Broussard touched briefly on the virtues of large-throughput systems in his background paper.

5/ OU comments: "Mr. Pieper is probably referring to the pipeline to the Forties field in his reference to the 32 inch, 420 foot depth line. Severe problems have been encountered. While the line will be successfully laid, it has run into extensive delays due to the water depth and weather conditions. Based upon the difficulties encountered in the Forties field, 'laying large diameter pipe at 900 feet' will be an engineering challenge of significant magnitude."

6/ Mr. Hallman wonders whether this optimism regarding pipelaying at greater depths is justified. He recalls Mr. Pieper's statements--in his own paper--that one "of the problems with high tension forces is the increased possibility of damage to pipe coatings. Another problem is the increased loading on the large anchoring system. These are problems that must be contended with as pipeline construction moves into deeper water."

7/ OU states that "the safety record is a more complex issue than this reference indicates. Due to safety problems with pipelines, the Office of Pipeline Safety was established in 1968. But this agency is underfunded and understaffed (see pages 193-200 of Energy Under the Oceans) and only has limited OCS jurisdiction. Different agencies have different reporting criteria. Mr. Broussard's paper in general restricts its attention to trunk pipelines, but the OCS hydrocarbon transportation system is a vast complex array of trunklines, flowlines and gathering lines, and many of the latter move hydrocarbons dozens of miles to a sales point (see Tables 11 and 26, pages 196 and 292 in Energy Under the Oceans, and note footnote e: perhaps thousands of miles of pipe are not systematically accounted for)."

8/ Mr. Hallman believes that Mr. Broussard relies too much, and inappropriately, on overland pipeline safety statistics.

9/ The OU group remarks: "In reference to Mr. Broussard's comment on multiphase pipelines, see page 125 of Energy Under the Oceans, we observe that 'it is not certain that a satisfactory multiphase pumping capability will be available within the next fifteen years.' Several companies have been investigating multiphase flow, including Mr. Broussard's own company, the Shell Oil Company."

10/ Mr. Hallman believes that the summary of this paper should have included a reference to (a) Mr. Broussard's judgment that careful land-use planning and management, as well as increased efforts to develop baseline scientific and engineering data are necessary to protect against environmental damage in the coastal zone; and (b) Mr. Broussard's endorsement of continued R&D efforts to develop solutions to problems unique to offshore systems in the Arctic region, to develop improved methods for monitoring external and internal corrosion of offshore pipelines, and to develop improved pipeline repair techniques.

11/ Mr. Hallman believes that there was inadequate discussion or analysis of the physical, environmental, or economic problems which may be encountered in the newer exploration areas; thus, it is impossible, he feels, to draw any firm conclusion (as a result of this panel's deliberations) about how risks arising unique to the newer areas can be managed by presently available technology.

12/ A general comment by the OU group: "We would like to see an emphasis on dealing with pipelines as a system, from the well-head to shore and beyond. In this manner, technical, safety, economic and environmental issues can focus on the overall transportation problem. The establishment of a pipeline network will be the significant issue in the new OCS areas, especially how this network of gathering, flow and trunklines interfaces with land-use, leasing, automated monitoring systems and an overall jurisdictional responsibility."

13/ Mr. Hallman observes that increased financial investment may also be a disincentive to deal with environmental and safety problems. He feels that financial considerations cannot replace the need for careful and rigorous regulation of OCS development to insure environmental protection.

14/ Mr. Hallman cautions about the applicability of experience with floating structures in such protected or calm waters as the Persian Gulf to the more hostile oceanic conditions of the Gulf of Alaska. He feels that more research and testing are highly desirable.

List of Participants
Panel on Transport and Storage
December 6, 1973

George Doumani (Chairman)	Library of Congress
Joel Darmstadter (Rapporteur)	Resources for the Future, Inc.
Douglas E. Broussard*	Shell Development Co.
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Richard F. Hill	Federal Power Commission
Price McDonald	U.S. Geological Survey
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SUPPLEMENTAL COMMENTS ON THE REPORT OF THE PANEL ON OIL SPILLS AND CONTAINMENT

The report of the Panel on Oil Spills and Containment generally gives a very erroneous impression of the discussions on the effects of oil and on the use of oil spill dispersants as a tool to combat oil spills. Further, the report then makes an assessment of U.S. policy towards the use of dispersants which is basically incorrect.

The published U.S. policy on the use of dispersants has been in effect since the publication of the National Oil and Hazardous Substances Pollution Contingency Plan in August of 1971. Since that time it has been widely discussed in scientific conferences and other arenas and shown to be a reasonable manner of closely controlling the use of such chemicals without totally prohibiting them. Further, an examination of the Plan does not support the view that it dictates a "strong aversion" to the use of chemical dispersants. What the Plan does do is advocate the use of methods, wherever possible, which will result in the removal and proper disposal of spilled oil,as opposed to methods which will leave the spilled oil in the environment. The use of other methods, such as dispersants, however, is not prohibited. In fact, a testing procedure is referenced in the Plan by which companies wishing to market dispersants may test their products for effectiveness and toxicity. The information is then submitted to EPA. After that, dispersants may be used in accordance with Annex X of the National Plan.

U.S. Environmental Protection Agency
U.S. Council on Environmental Quality
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